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by the Ontario Geological Survey

edited by
John Wood, Owen L. White, R.B. Barlow, and A.C. Colvine

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FOREWORD

During 1982, the Ontario Geological Survey carried out a large number of independent geological, geophysical, geochemical, geochronological, and mineral deposit studies. In addition, studies were undertaken in cooperation with the ministry's regional geological staff, personnel from a number of universities, and several private consulting firms. Project involvement is summarized in the section introductions and individual summaries.

Funding for a number of regional stimulation projects was provided by the Ontario Ministry of Northern Affairs, the Government of Canada, and the Ontario Ministry of Natural Resources, and for Hydrocarbon Energy Resources Program (HERP) by the Ontario Ministry of Treasury and Economics under the Board of Industrial Leadership and Development (BILD) Program. Funding acknowledgments are given in the individual summaries.

The locations of the areas investigated are shown on 2 maps of the Province at the beginning of this report. The preliminary results of the work are outlined in this summary, which contains reports prepared by leaders of each of the projects. In these reports, some emphasis has been placed on the economic aspects of the different investigations. It is the hope of the Ontario Geological Survey that the information thus provided will help in the mineral resource evaluation of these areas, and so will be a valuable aid to mineral prospecting and resource planning in the Province. Also, as a direct result of this summer's work, research was undertaken on a number of theses at the B.Sc. and graduate level.

Coloured maps and final detailed reports covering most of the field projects are being prepared for publication. In the interim, uncoloured preliminary geoscience maps with comprehensive marginal notes will be released for distribution, mainly during the winter of 1982-83. Notices of the releases will be mailed to all persons or organizations on the Mineral Resources group notification list, and will be published in the technical journals and other media.

E.G. Pye
Director
Ontario Geological Survey

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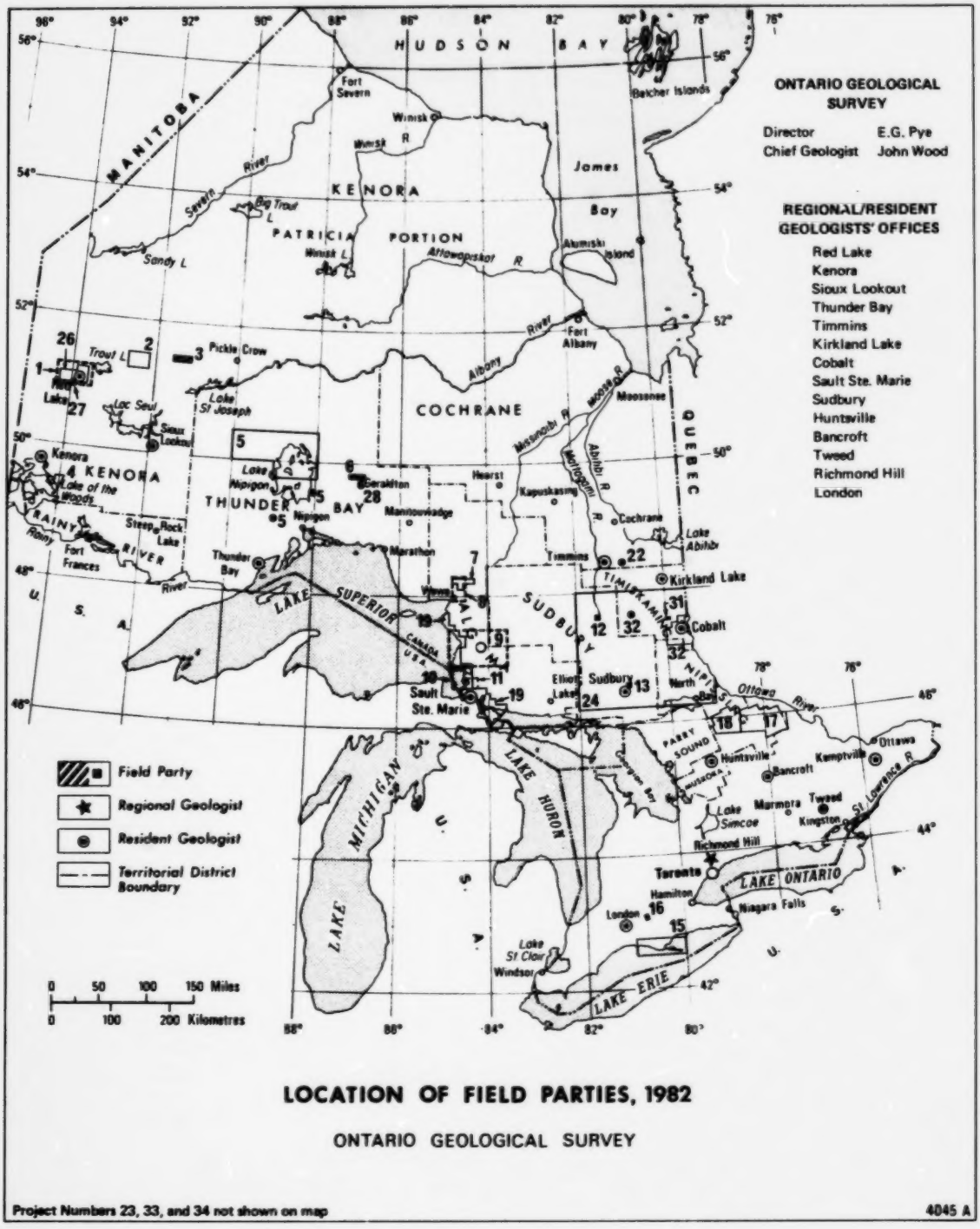
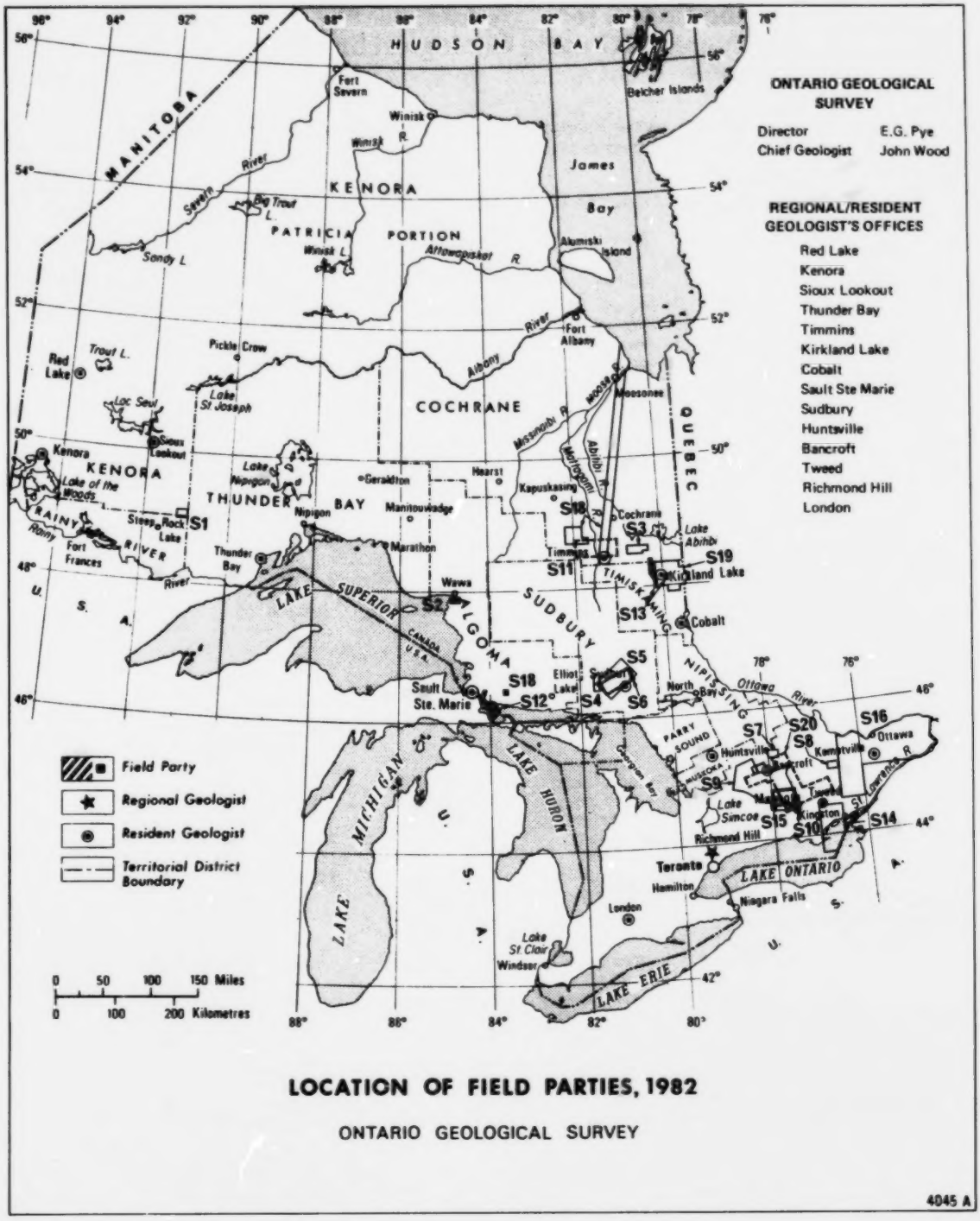


LOCATION OF FIELD PARTIES, 1982

ONTARIO GEOLOGICAL SURVEY

Project Numbers 23, 33, and 34 not shown on map **4045 A**

Location of Field Parties of the Ontario Geological Survey, 1982.



LOCATION OF FIELD PARTIES, 1982

ONTARIO GEOLOGICAL SURVEY

Location of Special Projects of the Ontario Geological Survey, 1982.

Conversion Factors for Measurements in Ontario Geological Survey Publications

If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE—Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in cooperation with the Coal Association of Canada.

Precambrian Geology Programs

Summary of Activities, Precambrian Geology Section, 1982

John Wood[1]

The fieldwork reported in this volume was carried out by 21 field parties, 16 under the direction of Section staff, 2 under the direction of Ontario Ministry of Natural Resources regional staff, and 3 under the direction of university personnel. Of these field parties 11 were directed towards detailed mapping at a scale of 1:15 840 for a total coverage of 3500 km^2, 1 involved reconnaissance mapping at a scale of 1:50 000, 6 were geared towards solving specific problems, and 3 were devoted to developing regional syntheses of areas already mapped in detail.

The Base Program of the Section funded 11 field crews. The objectives of the Base Program are to provide geologic data; geologic interpretation and concepts which will increase the effectiveness of mineral exploration; and mineral resource potential evaluation and management throughout the 650 000 km^2 of Ontario underlain by Precambrian bedrock. Base Program projects were directed towards readily accessible, high to moderate mineral potential areas for maximum cost-effectiveness. The remainder of the field projects whose goals are directed more specifically at a geological problem, or region, or community were funded:

1. by the Ontario Ministry of Northern Affairs (NOGS)
2. jointly by the Federal Government and the Ontario Government (NORDA)
3. jointly by the Ontario Ministry of Natural Resources and the Federal Government under the Eastern Ontario Subsidiary Agreement (SOGS)
4. jointly by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources (Black River-Matheson)

The source of funding other than from the Base Budget is shown on the individual summaries.

Fieldwork was undertaken in Superior Province, Southern Province, and Grenville Province. Individual project summaries are arranged accordingly but also reflect geographical ordering from northwest to southeast.

Within Uchi Subprovince, Henry Wallace continued a comprehensive tectono-stratigraphic synthesis of the Red Lake area. This summer saw resolution of stratigraphic and genetic problems of epiclastic and pyroclastic rocks in Fairlie and Todd Townships; the assignment of a pyroclastic origin to a rock sequence in Fairlie Township previously considered to be epiclastic; the documentation of an alteration style, in the metavolcanics of the Pipestone Bay area, similar in many respects to the alteration in Dome and Balmer Townships; in northeastern Baird Township rocks previously interpreted as metavolcanics were recognized to be predominantly altered mafic flows; and the establishment of a relationship between strata-parallel faults and alteration, and hence potentially, gold mineralization.

In the Birch Lake area, S.E. Nelson undertook a sedimentological study of the Birch Lake metasediments. The object is to establish the depositional environments of the metasediments and establish facies relationships with other rock types in the area, particularly with respect to wacke-hosted gold mineralization at the eastern end of Birch Lake.

In the Meen Lake area, west of Pickle Lake, G.M. Stott began a multi-year detailed mapping program. This summer's work has outlined a previously undefined major group of

[1]Chief Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

felsic to intermediate metavolcanics. Two other groups complete the supracrustal stratigraphy. A structural analysis of the belt is off to a sound start.

Within Wabigoon Subprovince, G.W. Johns continued detailed mapping of the Long Bay area. Refinement of the stratigraphy continues to be hampered by complex deformation related, at least in part, to 3 batholithic bodies. The area has considerable potential for gold and base metals; gold in particular could occur in a number of environments.

In the Lumby Lake area, M.C. Jackson started a 2-year detailed mapping project which has added significantly to previous work. The area has potential for gold and base metals, the latter enhanced by the discovery of numerous thin felsic metavolcanic units and the former by the recognition of ankeritic carbonate zones hosting quartz veins, a lithology known to host gold elsewhere in the area.

In the Lake Nipigon area, R.H. Sutcliffe continued reconnaissance mapping of Early Precambrian (Archean) Wabigoon Subprovince rocks and Late Precambrian (Proterozoic) rocks of the Nipigon Plate. The results are exceedingly interesting: Late Precambrian felsic volcanic and subvolcanic rocks occur within the Nipigon Plate; large cone sheets are the feeder zones for the Logan diabase sills; quartz arenite units, probably correlative with the Sibley Group, occur at the north end of Lake Nipigon. The area has potential for copper, nickel, chrome, platinum, uranium, and lithophile mineralization.

In the Geraldton area, G.P. Beakhouse mapped 3 townships in detail. Five lithological associations are outlined, and suggestions are made for base metal and gold exploration.

In the Wawa part of Abitibi Subprovince, N.W.D. Massey began a 2-year program by mapping in detail Rabazo and Naveau Townships, located just to the south of the Town of Wawa. Gold occurs in supracrustal rocks and in both felsic and mafic intrusions. The gold potential of thin, discontinuous, iron formation units is still to be assessed.

R.P. Sage continued his long-term detailed mapping program in the Wawa area and continues to build on the regional stratigraphy so far established. There are numerous large iron deposits in the area, and combined with the extensive chloritoid alteration and less extensive tourmaline alteration, the area has to be considered of prime importance for economic mineralization of several types.

In the Batchawana area, E.C. Grunsky continued a synoptic mapping program which entailed both detailed and reconnaissance mapping that has changed some previous lithologic interpretations. The area has had 2 significant copper producers, both of Late Precambrian age. This summer's work has outlined regional structures that may aid in extrapolating the regional stratigraphy of the Early Precambrian supracrustal rocks, and hence, continuity of economically favourable stratigraphic horizons.

In the Swayze Belt, G.M. Siragusa mapped Brunswick Township which adjoins the eastern boundary of the Pensyl Lake area. The township has received little exploration attention, but some lithologies within the supracrustal assemblage warrant prospecting.

In the eastern part of Abitibi Subprovince, N.F. Trowell initiated a multi-year program of detailed, synoptic, and stratigraphic mapping along the Destor-Porcupine Fault from east of Timmins to the Quebec border, by mapping in detail some 400 km^2 in the Matheson area. The challenge of this area is the required geological extrapolation from areas of excellent outcrop to areas of sparse outcrop. The area has considerable exploration potential, especially for gold.

In the central part of Superior Province within Ontario, there are a number of mostly post-Early Precambrian dike swarms. Richard E. Ernst measured, described, and sampled a number of individual dikes as the first part of a Ph.D. thesis devoted to the structural and chemical analyses of the dike swarms. This summer's work shows that there are regional variations within individual dikes and swarms, and gives promise that future work will be useful in further unravelling the tectonic and magmatic history of shield areas.

In Southern Province, A.G. Choudhry mapped in detail a previously unmapped area, near Levack, of Middle Precambrian Huronian rocks and Early Precambrian gneissic and migmatitic rocks. All Huronian formations from the Mississagi Formation to the Lorrain Formation are represented. The area has potential for placer uranium mineralization in Huro-

nian rocks; and base-metal mineralization in contact areas of the Espanola and Serpent Formation with Nipissing Diabase intrusions

In the Ile Parisienne and Rudderhead Point areas, P.E. Giblin completed detailed mapping of rocks that range in age from Early Precambrian to Paleozoic. As well as documenting the geology work, this has resolved some regional correlation problems.

In the Goulais River area, P.E. Giblin completed detailed mapping of Early Precambrian supracrustal and plutonic rocks, Middle to Late Precambrian supracrustal and intrusive rocks, and supracrustal rocks of probable Paleozoic age. In addition to the Huronian Gowganda and Lorrain Formations, the area also contains rocks of the Thessalon and Aweres Formations, which are now considered to be, at least in part, correlative with the Elliot Lake Group. The area has copper and uranium potential.

In the Sudbury area, Burkhard O. Dressler completed a 4-year study of the Footwall and Sublayer of the Sudbury Igneous Complex. This year's work has resolved the age relationship of the Sublayer to the norite, has shown that in the South Range a Sudbury Breccia body appears to host 2 orebodies, and explained the conflicting relationships of the norite with the Murray and Creighton Granites.

In the Sudbury area also, T.L. Muir studied the Onaping Formation, one of nature's enigmas. Muir outlines a number of significant features of the Onaping Formation and concludes that part of the formation has a significant potential for economic mineralization.

Within the Regional Municipality of Sudbury, P.E. Giblin commenced detailed mapping of Garson Township. The area mapped is underlain predominantly by rocks of the Huronian Supergroup, the Whitewater Group, and the Sudbury Igneous Complex.

Within the Grenville Province, Marika S. Bourque continued her study of the stratigraphy and sedimentation of carbonate metasediments in the Havelock-Madoc-Bancroft area. This year's fieldwork has revealed stylofibrous cement and geopetal structures in dolomites, and has shown that these dolomites are areally extensive and useful as marker horizons. Stromatolites, both columnar and domal, occur in the dolomites and are proving an important tool in the reconstruction of sedimentary environments and paleogeography.

In the vicinity of Bancroft, F.W. Breaks and R. Thivierge mapped in detail a 280 km^2 area of exceedingly complex geology that includes local occurrences of granulite facies rocks. This survey contributes much new information on all aspects of the geology of this area.

In the Lavant area, Liba Pauk continued detailed mapping of a complex geological area, the regional stratigraphy and structure of which continues to be unravelled. The area has a mineral exploration history dating back to the 1880s and has potential for several varieties of metallic and non-metallic mineral deposits.

In the vicinity of the Village of Actinolite, C.P. Verschuren investigated in detail a talc occurrence that has been known since before the turn of the century but remained unexplored until recently. The origin of the talc mineralization is not yet clear, several potential origins are suggested, along with pointers on exploration for similar deposits.

The summaries contained in this volume represent a first appraisal of raw geological field data, as do the preliminary maps which are in preparation for publication during the 1982-83 winter period. These summaries and maps were designed as a means to rapidly disseminate "highlights" and to present general outlines of new information. Extended analysis of field data, in conjunction with detailed office and laboratory research, for final report and map publication, can be expected to result in changes to the field terminology, interpretations, and concepts expressed in this summary.

No. 1 Red Lake Synoptic Project, District of Kenora

Henry Wallace[1]

Introduction

Gold exploration in the Red Lake belt has been hampered for many years by the lack of detailed, up-to-date, published information on the geology of the area. The objective of this project is to produce a comprehensive tectono-stratigraphic synthesis of that belt, and to relate its gold deposits to factors controlling metallogenesis.

Since 1980, the author has examined most of the supracrustal rocks of the Red Lake belt on a reconnaissance scale to become familiar with areas previously mapped by several other Ontario Geological Survey geologists on a township by township basis. Problems of stratigraphic correlation between township map-areas were largely resolved during this reconnaissance (Wallace 1980) and in 1981, Baird Township, one of only two townships which at that time had not been geologically surveyed since 1970, was mapped in detail by the author and assistants (Wallace 1981). Petrochemical and geochronologic data arising from this work has been used to solve problems of long range correlation within the Red Lake belt and adjacent areas (Thurston *et al.* 1981).

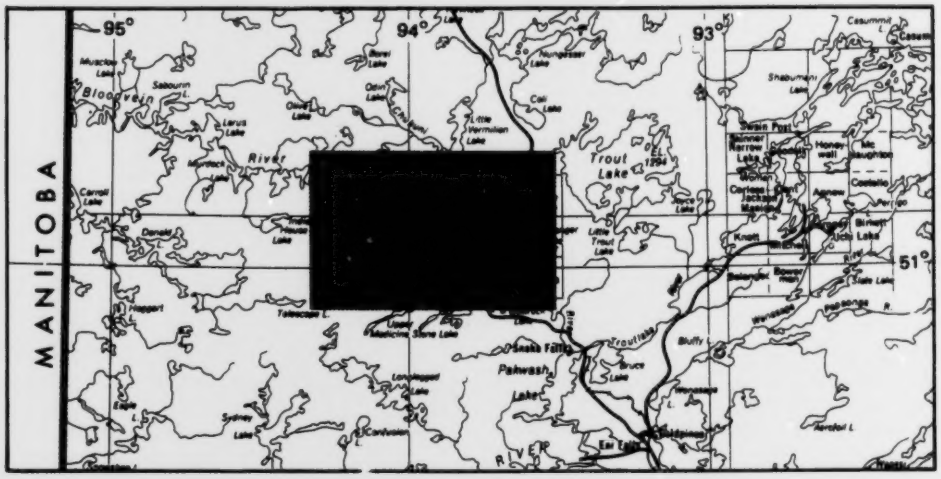
[1]Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

Present Survey

Results of the author's 1982 field work, most of which was carried out in the eastern part of the Red Lake belt, are summarized below.

Relationships between north-facing clastic sequences along the southern sides of Martin and Wolf Bays in Fairlie and adjacent Todd Townships have been clarified. Around Martin Bay, the clastic rocks are predominantly pyroclastic rocks, including possible ash flows, and resedimented pyroclastic deposits which are overlain by a poorly-exposed wacke-mudstone sequence under most of the bay. To the west, around Wolf Bay, the pyroclastic sequence thins appreciably and interfingers with wacke-mudstone units and chemical metasediments. This westward facies change from predominantly pyroclastic to epiclastic appears complete on the Wolf Islands at the mouth of Wolf Bay, where recognizable pyroclastic beds were not found.

North of Red Lake in Fairlie Township, the existing geological map (Riley 1978) shows a broad east-northeast-trending belt of folded clastic metasediments consisting predominantly of wacke-mudstone with several thick polymictic conglomerate sequences. This is in conflict with the findings of Pirie *et al.* (1977) in the adja-



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

cent part of McDonough Township where pyroclastic rocks were recognized. The author's field work indicates that approximately 1 km north of the contact between the mafic metavolcanics along the northern shore of Red Lake and these overlying clastic "metasediments" there is a significant change in the nature of the clastic rocks. Immediately north of this abrupt contact, felsic pyroclastic rocks, mostly crystal-rich tuff and lapilli-tuff units predominate. Traversing northward from the contact, pyroclastic units are intermixed with clast-supported conglomeratic beds containing little other than felsic to intermediate metavolcanic clasts. By contrast, conglomerates and pebbly sandstone units associated with the wacke-mudstone sequence south of the contact contain a variety of intrusive, chemical metasedimentary, and mafic metavolcanic clasts. It seems most unlikely that the northern pyroclastic and southern epiclastic sequences are facies equivalents on opposing limbs of a fold, but rather that they are conformable. Reliable stratigraphic top indicators are scarce in this part of the area, but available information suggests that the pyroclastic sequence faces northward and overlies the epiclastic rocks.

Several small gold and sulphide mineral occurrences have been found in the vicinity of this pyroclastic-epiclastic contact.

Alteration similar in some respects to that found in Pirie's (1981) "highly altered zone" in northeastern Dome and adjacent Balmer Townships also occurs around Pipestone Bay at the western end of the Red Lake belt. Silicification, soda depletion, and to a lesser extent, carbonatization have affected mafic and felsic calc-alkalic metavolcanics in a stratiform zone passing through Middle and Sadler Bays, and extending northward to the Rowan Lake and Mount Jamie Mine areas. Near the mines, garnet and andalusite have developed in some metavolcanics, reflecting their alkali and particularly soda-poor chemistry. Trace element variations such as the anomalous enrichment of arsenic and antimony found by Pirie (1981) in Dome and Balmer Townships, were not observed in rocks around Pipestone Bay.

Preliminary geochronologic results indicate that the rocks of the Pipestone Bay area may be roughly the same age, 2.9 Ga (F. Corfu, Royal Ontario Museum, Toronto, Ontario, personal communication, 1982), as the tholeiitic to komatiitic sequence which hosts the major gold deposits in Balmertown and Cochenour. The similarity in age and alteration characteristics of the rocks from these two areas, plus the concentration of known gold occurrences within them, tend to support the hypothesis that gold mineralization in this belt is stratigraphically controlled, at least on a crude scale.

Minor fold axes, penetrative axial planar foliations, and lineations in eastern Dome Township support the existence of a major, moderately westward-plunging antiform in the eastern part of the belt, as was first proposed by Pirie *et al.* (1978). The structural picture, however, may not be simple. Overturning of graded beds in folded clastic rocks north of McKenzie Island suggests that two periods of folding may have produced the complex deformation pattern in that part of the belt. Such a tectonic history may apply throughout the region, but assessment of that possibility must await further field investigations.

Mapping in the poorly exposed northeastern part of Baird Township indicates that sequences previously interpreted as felsic metavolcanics (Ferguson 1965) are predominantly altered mafic flows. In some places pillows are clearly discernible with tops to the north. Chemical analyses of these rocks show the familiar pattern of soda depletion and silicification. Locally, pods of massive brown-weathering dolomite of unknown dimensions cross-cut the flows and siliceous interflow units which may represent altered tuff or chemical metasediments. Only traces of gold were found in quartz vein samples cutting the carbonate pods.

In Bateman, southern McDonough, and northern Dome Townships, there is evidence for several northeast-trending strata-parallel faults, some of which, such as the Post Narrows fault, probably extend for several kilometres. Zones of intense carbonatization and carbonate veining, strong mineral foliation, and, in some cases, mylonitization, which mark these faults on outcrop, are generally narrow: tens of metres at the most. Deformation outside these zones is minimal, and many more such faults undoubtedly exist under Red Lake, Hoyles Bay, and poorly exposed parts of Bateman, Dome, and Balmer Townships.

Strata-parallel faults such as these probably play an important role in localizing gold mineralization. In particular, where these faults occur along contacts between lithologies with a strong competency contrast, such as between mafic metavolcanics and ultramafic intrusive rocks, dilatant zones develop which tend to take the form of pipe-like lenses parallel to the plunge of the regional fold axis. Such zones are obvious conduits for mineralizing solutions.

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No. 2 Birch Lake Area, District of Kenora (Patricia Portion)

S.E. Nelson[1]

Introduction

The area is located 120 km northeast of Red Lake, and consists of South Bay, Exit Bay, and Wagner Bay, which make up the southern half of Birch Lake. Access to the area is easiest by float plane, but Birch Lake can also be reached from Highway 657 by boat with a few portages.

The most recent mapping of the area has been done by Thurston (1977, 1978b) and Thurston *et al.* (1981). The purpose of this project is to study the metasediments of the area. Specific objectives are to determine the environment of deposition of metaconglomerate and metawacke units, their mutual relationships, and their provenance, with a view to development of a stratigraphic, evolutionary, and facies model of the metasedimentary part of the Birch Lake belt.

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Mineral Exploration

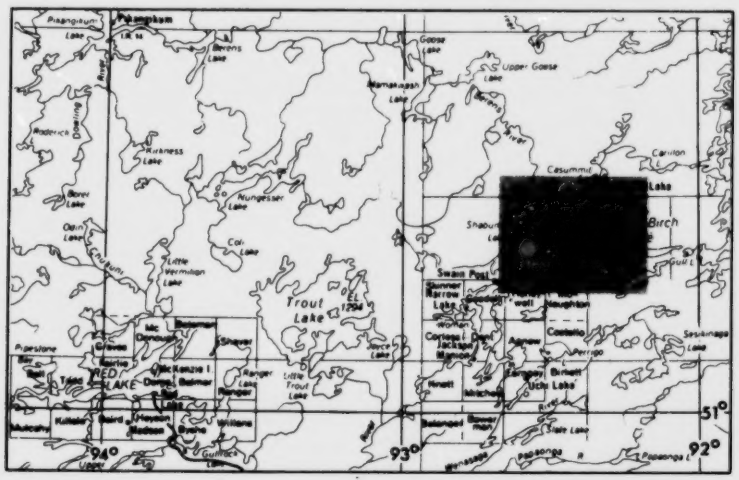
Past mineral exploration in the area has been summarized by Thurston (1977, 1978b).

General Geology

The study area lies within the Early Precambrian (Archean) Birch-Uchi Lake metasedimentary-metavolcanic belt of the Uchi Subprovince. Thurston (1978a) has subdivided the largely metavolcanic stratigraphy to the south into 3 major mafic to felsic cycles. His preliminary work in the Birch Lake area revealed that felsic metavolcanics in the central part of Birch Lake are correlative with Cycle III, the youngest cycle, and that the Birch Lake metasediments are younger than Cycle III. The rocks are generally metamorphosed to greenschist grade, but locally amphibolite grade rocks are present.

The best exposures of metasediments are along the shore of Birch Lake. The stratigraphy comprises 3 major rock types:

1. Clast-supported boulder and cobble metaconglomerates contain interbedded coarse-grained meta-arkos-



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

es. The clast types include felsic to intermediate metavolcanics, mafic metavolcanics, and chert in order of abundance. The conglomerates were mapped in terms of clast types, size and degree of rounding of clasts, type and thickness of bedding, and character of the matrix. The intercalated arkoses have been characterized in terms of bed thickness and type.

2. Fine-grained to medium-grained wackes which contain small-scale crossbedding and display Bouma (1962) A, B, and C beds, have been mapped in terms of orientation, type and thickness of crossbeds, bed thickness of planar beds, and clast size and type.

3. An intermediate to felsic pyroclastic unit which wedges into the epiclastic sequence, consists of tuff and lapilli-tuff, is poorly bedded, and contains fragments of andesite to dacite bulk composition in a coarse (1 to 3 mm) matrix of similar composition with 10 percent euhedral to subhedral plagioclase phenocrysts. This unit appears, on the basis of the presence and thickness of bedding, lack of pumice, lack of a fine-grained tuffaceous top, and lack of grading, to be a proximal debris flow deposit. Given that its position is relatively high in the metasedimentary stratigraphy, well above the Cycle III metavolcanics, the unit may represent post-Cycle III calc-alkaline andesitic volcanism.

These lithologies are distributed as follows:

South Bay: metaconglomerates dominate in the southwest. Towards the northeast, the rocks become increasingly finer grained and more wacke is present.

At the mouth of Exit Bay there are several good outcrops of wacke containing abundant crossbedding. Towards the east, the pyroclastic wedge is exposed.

In the southwestern part of Wagner Bay, the rocks are primarily wacke. To the northeast and east, conglomerates much like those of South Bay are encountered. Some beds contain magnetic iron formation. The pyroclastic unit occurs to the north. Some of the pyroclastic layers contain abundant magnetite.

Structural Geology

The rocks of South Bay generally strike northwesterly, and dip steeply to the southwest. Tops in the area, based on graded beds, are generally to the north-northeast.

The rocks of Exit Bay tend to have the same strike, dip, and tops as those of South Bay. The rocks of Wagner Bay vary in strike from north-trending to northwest-trending, and dip to the northeast between 50° and 90°. Graded beds show that tops are generally to the southwest.

A major syncline extends westerly between Exit Bay and Wagner Bay. There is general fining upwards towards the centre of the syncline, from conglomerate to wacke. Measurements on minor fold axes reveal that the syncline plunges to the east-northeast at 20° to 50°.

There is also a well developed cleavage throughout the area. The cleavage is consistently at low to moderate angles to bedding.

Subsequent Investigations

Laboratory analysis of the field data will include definition of a facies sequence, and will hopefully lead to postulation of a facies model and environment of deposition for the Birch Lake metasediments. The elucidation of the paleoenvironment of this sequence will place controls on the wacke-hosted gold mineralization at the east end of Birch Lake (Thurston 1978b). It will also lead to an increased understanding of the evolution of the Birch-Uchi metavolcanic-metasedimentary belt, and to a closer comparison with evolutionary models for layer "greenstone belts" (Eriksson 1980).

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No. 3 Meen Lake Area, District of Kenora (Patricia Portion)

G.M. Stott[1]

Introduction

The Meen Lake Area is centred approximately 80 km west of Pickle Lake and includes the western part of a major Early Precambrian supracrustal mass that extends eastward to Pickle Lake and southward to Lake St. Joseph. The project area lies between Latitudes 51°22.5'N and 51°30'N, and Longitudes 91°04'W and 91°34'W, and covers 483 km².

This project begins a multi-year detailed mapping program to update our knowledge of supracrustal stratigraphy and structure in this region. In 1972, this area was included in a reconnaissance survey by the Ontario Division of Mines (Sage *et al.* 1975, Sage and Breaks 1982) and earlier it formed part of the region covered by a more generalized reconnaissance program of the Geological Survey of Canada (Emslie 1960).

Access to the area is by float plane from Pickle Lake. The percentage of outcrop exposure is varied but generally low.

Significant changes from previously published maps of this area are the result of the present survey (Figure 1 and compare with Sage *et al.* 1975).

In particular, a previously undefined suite of felsic to intermediate pyroclastic and associated rocks is found to comprise a major stratigraphic package in the vicinity of Meen Lake.

A computer-based field data record system, originally designed by Lambert and Reesor (1974) and subsequently revised by Lambert in 1975, is being tested in this program and will be further revised in subsequent years. This system should provide an improved storage, processing, and accessing capability for the map data base.

Mineral Exploration

Records of the Resident Geologist's Files, Ontario Ministry of Natural Resources, Sioux Lookout, indicate that there has been limited exploration activity in the Meen Lake area. The following information is extracted from those files.

In 1962, Jorsco Explorations Limited conducted geological and ground electromagnetic and magnetic surveys on their property north of eastern Meen Lake. Two

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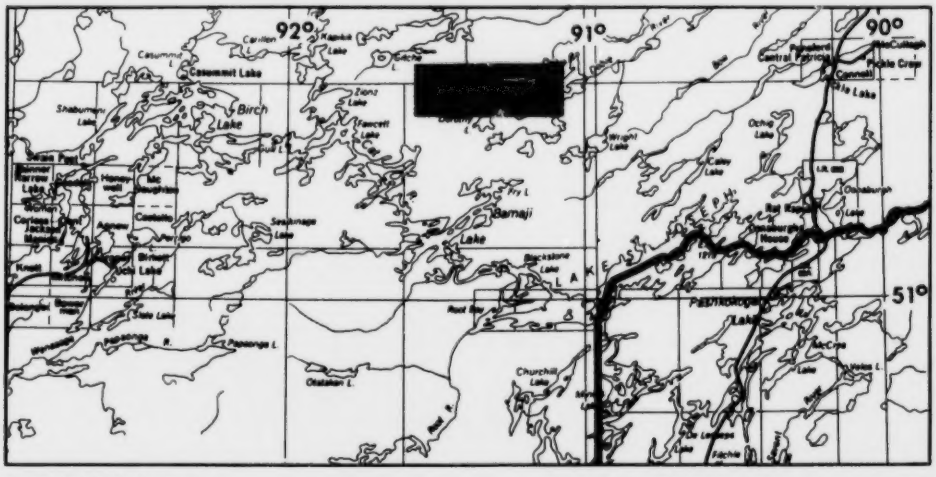

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

electromagnetic conductors were located that are proximally associated with narrow ironstone units. Sulphide mineralization was found associated with ironstone on claim KRL 49039, close to the northern metavolcanic contact.

Cominco Limited conducted a number of surveys over the area, commencing with a geological survey (private company data not on public file) in 1978. Based on the latter, a number of anomalies were selected for ground magnetic and horizontal loop electromagnetic follow-up in 1979, and 4 grids were chosen for gravity profiling. In 1980, a total field magnetic survey was conducted on a block of claims southeast of Meen Lake. Results from these surveys have established the existence of magnetic anomalies and horizontal loop electromagnetic conductors that were tested by diamond drilling. Three diamond-drill holes southeast of Meen Lake have outlined a zone of conductive massive pyrite, pyrrhotite, and graphite metasediments and cherty sulphide ironstone within a suite of felsic tuff to tuff-breccia and volcanically derived metasediment. These rocks are part of the Upper Meen Lake sequence described below.

Union Miniere Explorations and Mining Corporation Limited completed an airborne magnetic and electromagnetic survey of the area in 1971, and an airborne geophysical survey jointly with Canadian Nickel Company Limited during 1972 to 1973. One conductive horizon near the southern margin of the belt within the Dorothy Lake sequence was drilled in 1975. A 3 m section of finely interbedded mafic tuff and chemical sediment was found to contain conductive stringers of pyrrhotite and pyrite. During the present survey this was found to be a distinctive mappable unit, possibly locally folded, but continuous along the length of the Dorothy Lake sequence. A linear magnetic anomaly on a lake south of Simard Lake appears to be associated with this unit.

General Geology

The Early Precambrian supracrustal belt in this area comprises 3 lithologic sequences, described below and outlined in Figure 1.

The lower Meen Lake sequence consists of massive mafic metavolcanics with associated gabbroic sills. Individual flows are observed to grade into pillow and pillow breccia facies with or without flow-top breccia. Variolitic textures appear to be confined to pillow margins. Porphyritic flows are uncommon, but a plagioclase-phyric mafic flow close to the northern margin of the Dorothy Lake sequence is a notable exception. Only minor volumes of felsic to intermediate flows and tuffs are found in this sequence. Alteration in the mafic flows is generally restricted to pillowed units. Feldspar-epidote-rich cores and interpillow material probably reflect deuteric alteration of these rocks. A set of thin ironstone units lies close to the northern margin, within the stratigraphically lowermost part of the metavolcanic belt. These ironstones, interlayered with mafic metavolcanics and local mudstones, form a stratigraphically continuous zone along the length of the belt.

The upper Meen Lake sequence is composed of intermediate to felsic pyroclastic rocks, minor flows with less abundant interlayered mafic flows, and volcanically derived clastic metasediments. The pyroclastic deposits are predominant, and appear to be centred along and south of the eastern arm of Meen Lake. Outcrop exposure is poor in this vicinity because of a major esker sand deposit trending to the southwest. Evidence for a volcanic centre in this part of the area includes:

1. a concentration of pyroclastic breccia to tuff-breccia in this vicinity, with lapilli-tuff, finer tuffaceous units, and metasediments becoming more predominant westward across the main part of Meen Lake and eastward towards Dobie River
2. the presence of a quartz porphyry intrusion, a small exposure of which occurs on the northern shore of the eastern arm, stratigraphically underlying the main pyroclastic deposit
3. the apparent concentration of mafic dikes in this vicinity

A major linear aeromagnetic anomaly lies within and follows the length of this sequence. As noted in the previous section, this anomaly may be related to a mappable ironstone unit with locally associated sulphide-bearing graphitic metasediments.

The Dorothy Lake sequence is composed of volcanically derived wackes, minor arenites, felsic tuffs, local conglomerate units, resedimented pyroclastic rocks, and minor mafic to intermediate flows and tuffs. The sequence occupies the southern margin of the metavolcanic belt, extending across Dorothy Lake westward through a series of unnamed lakes on the Dobie River system.

The relationship between this sequence and the upper Meen Lake sequence of pyroclastic rocks is uncertain, but tentative structural evidence suggests they may be correlative, with the former constituting a sedimentary basin proximal to a major volcanic edifice to the north which produced the upper Meen Lake sequence. The Dorothy Lake sequence is possibly continuous with the sedimentary suite north of Fry Lake (Wallace 1979) which partially envelopes the Obaskaka Lake pluton south of the Meen Lake area (Sage *et al.* 1975).

A small ultramafic body, with a semicircular magnetic expression, intrudes the Dorothy Lake sequence close to the southern margin of the belt.

Granitoid rocks occur to the north, south, and west of the supracrustal belt. The northern domain is the most complex of the granitoid terrains. It is largely composed of the syntectonic Dobie Lake Batholith, a generally homogeneous equigranular tonalitic body which has intruded and deformed an older, finer grained tonalitic gneiss preserved in the southeastern corner of the project area south of the Obaskaka River. This batholith also contains some supracrustal remnants, notably north of Wellein

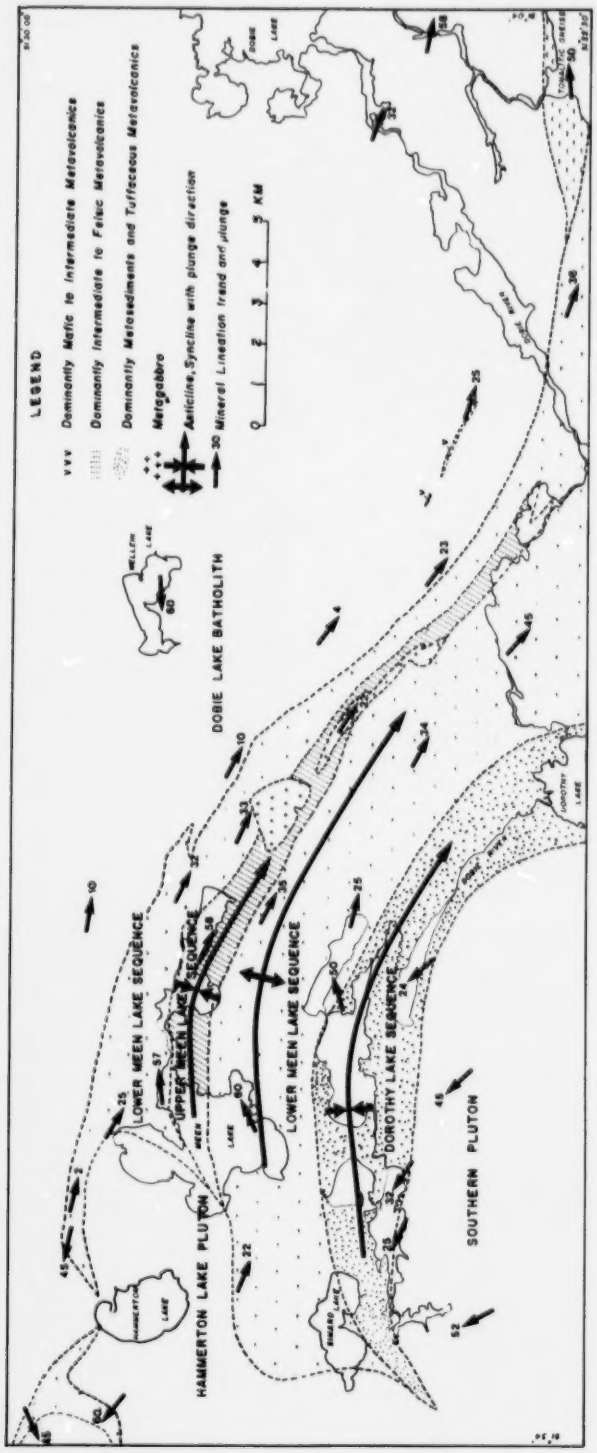

Figure 1—General stratigraphy and structure of the Meen Lake area.

Lake where amphibolite and gabbro "rafts" occur, and just west of Dobie River where there is a "screen" of amphibolite xenoliths. The latter partially envelopes and separates a portion from the main mass of the batholith, forming a parasitic oval dome-like structure within the batholith adjacent to the belt.

A younger quartz porphyritic granodiorite occupies the northwestern corner of the project area and appears to be related to the Hammerton Lake pluton.

The Hammerton Lake body is a late tectonic, massive, locally quartz porphyritic intrusion with a potassium feldspar porphyry phase west of Hammerton Lake. This intrusion has invaded the metavolcanic terrain north and northwest of Hammerton Lake, to the extent that the belt there exists as only a narrow zone of amphibolite margined by interlayered metavolcanic slivers and granodiorite.

The southern granitoid domain west of Dorothy Lake comprises a late tectonic, homogeneous trondhjemite-granodiorite body with a sharp northern contact. Although it contains no supracrustal inclusions, minor inclusions of an older, finer grained tonalite are locally evident within the pluton.

Structural Geology

Structurally, the Meen Lake belt is comprised of 2 major synclines, one coaxial with the upper Meen Lake sequence, and the other with the Dorothy Lake sequence, with an intervening anticline (Figure 1). These megascopic folds plunge 35° to 50° to the east and southeast, generally parallel to mineral lineations. Structural facing directions (younging sense of the folded stratigraphy) are to the east and southeast. The stratigraphy north of Meen Lake dips steeply (up to vertical) southward, whereas the southern three-fourths of the belt dips moderately northward. As a consequence, the megascopic fanning of foliations is centred on the Meen Lake syncline, which appears to be an upright structure plunging eastward. The other 2 megascopic folds to the south have inclined axial planes. No major megascopic ductile shear zones are recognized within this belt.

The easterly plunging stretching direction of the tectonic strain fabric, as manifested by mineral lineations, is characteristic across the width of the belt. This fabric orientation also continues into the adjacent Dobie Lake Batholith, tentatively implying that the rise of this batholith may be responsible for the easterly plunging fabric within the belt. Not enough is known, however, about the strain pattern across the batholith to test this hypothesis adequately.

North of Hammerton Lake, the strain fabric plunges westward, suggesting that a doubly plunging fold structure occurs with its apex north of Meen Lake. The northern contact of the belt is marked by a major mylonite zone within the granitoid rocks that exhibits prominent quartz ribboning across a width of several metres to tens of metres near the metavolcanics. This appears to be a late left-lateral zone of ductile simple shear.

A second major deformation is recorded within the metavolcanic belt close to its southern margin. This appears to be a contact strain aureole superimposed by the southern pluton upon the pre-existing easterly plunging regional strain fabric. This second deformation has produced a pronounced flattening and westerly plunging stretching fabric within the southern limb of the syncline in the Dorothy Lake sequence. The contact strain aureole extends for a width of 1.6 km north of the pluton contact and is clearly seen to deform the older easterly plunging fabric. A metamorphic aureole of amphibolite facies rank is also present.

The southern pluton itself possesses a primary westerly plunging mineral lineation parallel to the stretching direction in its strain aureole. This late to posttectonic intrusion postdates the granitoid bodies that lie north of the belt. The Hammerton Lake pluton, which is of similar tectonic setting, also possesses a locally developed narrow contact strain aureole.

Economic Geology and Suggestions for Exploration

Base Metals

The present mapping survey has outlined a previously undefined major felsic to intermediate metavolcanic suite that extends through Meen Lake along its southern shore, and southeastward towards Dobie River. The centre of volcanism appears to be in the vicinity of the eastern arm of Meen Lake. Such coarse pyroclastic deposits constitute an important target for base-metal exploration.

Since this area is partially blanketed by the thick sand deposit of a major esker, consideration should be given to geophysical methods that will adequately penetrate the overburden. No base-metal assays are available on public record.

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No. 4 Long Bay Area, District of Kenora

G.W. Johns[1]

Introduction

A mapping project in the eastern Lake of the Woods region, begun in 1981 by the author (Johns 1981), was continued during the summer of 1982 and an additional area of 407 km² was mapped at a scale of 1:15 840. The area south of Long Bay to Latitude 49°22'30''N, and from Longitudes 94°04'W to 94°15'W was completed; as well as an area bounded by Latitudes 49°22'30''N and 49°30'53''N, and Longitude 94°04'W and the eastern boundary (as shown on the Location Map). The village of Sioux Narrows in the southwestern part of the area is 48 km southeast of the Town of Kenora. Most of the map-area may be reached by boat from Sioux Narrows on Lake of the Woods and from Berry Lake, while the rest of the area may be reached by truck from Highway 71 and from a forest access road found along the north shore of Lobstick Bay.

Mineral Exploration

Gold has been the focus for exploration in the Lake of the Woods region since the turn of the century and many mines and prospects exist. Within the present map-area, two properties underwent underground development. The Regina Mine, 3.2 km southeast of Sioux Narrows has a 550-foot deep shaft and 3000 feet of lateral development, and operated sporadically from 1895 to 1943 (Beard and Garratt 1976). The Neda Mine on the Abraham claims, south-southeast of the Regina Mine, had a 40-foot shaft sunk on a 1000 foot-long shear zone in mafic metavolcanics (Assessment Files, Resident Geologist's Office, Kenora).

The northern contact zone between the Regina Bay stock and the mafic metavolcanics has been prospected for gold since before 1940. R. Bouska trenched and sampled shear zones west of the Sioux Narrows Provincial Park between Regina Bay and Highway 71 (Assessment Files, Resident Geologist's Office, Kenora). The Gaudry Occurrence, located east of the Provincial Park between Regina Bay and Highway 71, was trenched and assayed by Mr. Gaudry prior to 1960. These claims were then optioned to Strathcona Mines Limited, who, between 1960 and 1962, mapped, trenched, and diamond drilled two holes. In 1980 and 1981, Sherritt Gordon Mines Limited completed a magnetometer survey on the Gaudry Occurrence. Along the north shore of Lobstick Bay, trenching and diamond drilling has been carried out on the Thrasher flourite-gold showing. The last work was com-

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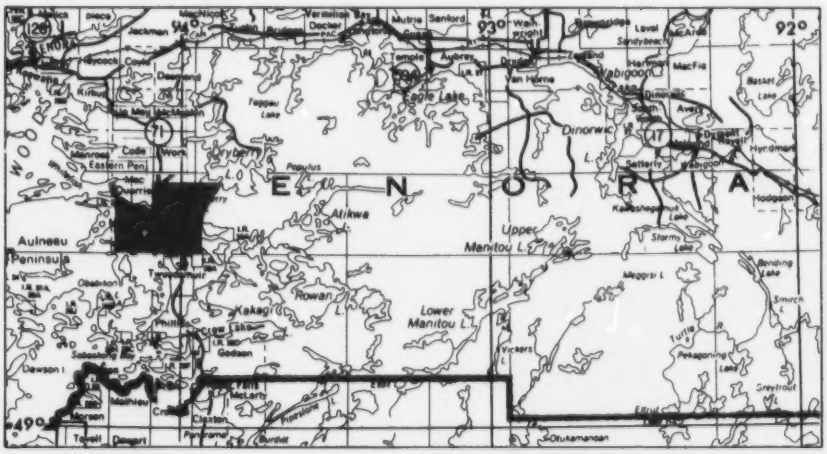
93°
92°
49°
Eagle Lake
Dinorwic L.
Satterly
Hodgson
Upper Manitou L.
Lower Manitou L.
Rowan
Aulneau Peninsula
Atikwa L.
Kakagi L.
Godson
Dawson I.
Clayton
Pentland
Sturtevant
Stukenonan
Storms Lake
Kawashegamuk Lake
Pentagoning Lake
Greystrout L.
Bending Lake
Smuch L.
Turtle L.
Vickers L.
Magpie L.
Wabigoon L.
Level
Sandybeach
Hardwood
MacFie
Bassett Lake
Dinorwic L.
Hyndman
Wabigoon
Kenora
Eastern Portage
Portage
Trapper Lake
Kinmount
Mt. Mary
Lac Seul
Code
Morrison
Wabigoon
Jackman
Vermilion Bay
Mutrie
Sanford
Walk
Wabigoon
Temple
Aubrey
Dryden
Perrault
Tenell
Dorion
Ear Falls
Mackenzie
Mackay
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Phillips
Gibson
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pleted in 1963 by Mr. Turturici (Assessment Files, Resident Geologist's Office, Kenora).

Canadian Nickel Company Limited diamond drilled three holes in the Lobstick Bay area between 1969 and 1972. Hudson Bay Exploration and Development Company Limited explored a large area around Sioux Narrows and to the northwest; in 1972 an airborne geophysical survey was done, with the ground magnetic and electromagnetic follow-up surveys being completed by 1975. In 1976 diamond drilling was carried out east of Rendezvous Point in MacQuarrie Township and southeast of Berry Lake (Assessment Files Research Office, Ontario Geological Survey, Toronto).

In 1973 Amax Exploration Incorporated diamond drilled one hole along the western side of Lobstick Bay. Selco Mining Corporation Limited explored a large area between Sioux Narrows and Dryden. In 1976, an INPUT survey was flown and in 1979, the claims in the present map-area had ground magnetic and electromagnetic surveys completed on them. In 1979 and 1980, diamond drilling was used to check some of the anomalies (Assessment Files Research Office, Ontario Geological Survey, Toronto). In 1981, Teck Exploration Limited diamond drilled one hole west of Whitefish Narrows (Assessment Files Research Office, Ontario Geological Survey, Toronto).

To the author's knowledge, no exploration was carried out within the map-area during the summer of 1982.

General Geology

Fraser (1943) mapped the Whitefish Bay area, Lake of the Woods, in 1937, and this included much of the western section of the present map-area. The eastern section was mapped by Burwash (1934) as part of a study covering a larger area. The Cedartree Lake area, to the south of the present area, was mapped by Davies and Morin (1976), and the area to the east was mapped by Davies (1973). The area north of Long Bay and west of Highway 71 was mapped by the author in 1981 (Johns 1981; Johns and Richey 1982).

Except for the Late Precambrian northwest-trending diabase dikes, the rocks exposed in the map-area are Early Precambrian (Archean) in age.

Two cycles of volcanism have been proposed (Johns 1981) but this year's mapping has cast doubt on the validity of this interpretation. Two separate geologic environments exist, separated by the Pipestone-Cameron Fault.

The metavolcanics south and southwest of the fault consist of fine-grained, massive, feldspar-phyric, and pillowed mafic metavolcanics with minor argillitic interflow metasediments of the Snake Bay Formation. As the fault is approached, the mafic metavolcanics become intercalated with intermediate to felsic tuff, tuff breccia, and minor wacke.

The metavolcanics and metasediments north and northeast of the Pipestone-Cameron Fault form a more complex assemblage. South of Berry Lake to Lobstick Bay, and to the east, there is a south-facing homoclinal sequence consisting of: amphibolite intruded by quartz-phyric granodiorite; overlain by wacke and arenite with some interbedded tuff; overlain by intermediate to felsic tuff, tuff breccia, and pyroclastic breccia; overlain by a thick, massive quartz-feldspar crystal tuff with interbedded homolithic pyroclastic breccia; overlain by a thin unit of mafic metavolcanics; and capped by a thick sequence of wackes with minor interbedded tuff and lapilli tuff. This homoclinal sequence is more disturbed west of Highway 71 where intermediate to felsic pyroclastic rocks of the Berry Complex become interdigitated with wacke. The Berry Complex has been dated, using U/Pb methods, at 2713.9 million years (Davis and Edwards 1982). The metavolcanics and metasediments north and northwest of Berry Lake have been structurally deformed by the intrusion of the Dryberry Batholith.

Ultramafic to mafic rocks have intruded the metavolcanic and metasedimentary sequences. Peridotite to gabbro differentiated sills and diorite sills are found in the Rendezvous Point area. Differentiated sills with a peridotite base grading through equigranular crystalline melanogabbro into gabbro, have intruded the metavolcanics and metasediments along the western and northern sides of Berry Lake and east of Kenu Lake.

The supracrustal rocks have been intruded by the Dryberry Batholith to the northeast, the Aulneau Batholith to the southwest, and the stock centred on Regina Bay.

The Dryberry Batholith consists of numerous phases; the oldest is a foliated tonalite. Younger peripheral phases include a medium-grained, massive biotite granodiorite centred on Mooseview Lake, and a quartz-phyric granodiorite that trends northeasterly from Berry Lake. This quartz-phyric phase contains large roof pendants or masses of metavolcanics, metasediments, and differentiated ultramafic to mafic intrusions that do not appear to have been displaced.

The Aulneau Batholith, which is centred on McGeorge Township, consists of numerous granodiorite phases, has intruded the base of the Snake Bay Formation, and has several granodiorite epiphyses related to it.

Both the Dryberry and Aulneau Batholiths have later porphyritic phases forming dikes and sills in the surrounding host rocks. A massive medium-grained hornblende tonalite stock centred on Regina Bay is wholly enclosed by the mafic metavolcanics of the Snake Bay Formation. Several plugs and dikes of this material are found in the surrounding metavolcanics.

A late, zoned, high-level stock similar to the Hope Lake and Flora Lake stocks (Heimlich 1965, 1966) intrudes the supracrustal sequence east of Kenu Lake. This medium-grained porphyritic syenodiorite is in a similar tectonic setting to the Taylor Lake stock which has been dated, using U/Pb methods, at 2695 million years by Davis *et al.* (1982).

Structural Geology

The mafic metavolcanics of the Snake Bay Formation face uniformly northeast. The Berry Complex, from Mist Inlet eastwards, is a homoclinal south-facing sequence that has been intruded by the differentiated ultramafic to mafic sills, and the granodiorite in Berry Lake. Berry Lake and the quartz-phyric granodiorite are the core of a large anticline, and the ultramafic to mafic sills are in the nose. Between Berry Lake, the Dryberry Batholith, and the area to the west, the stratigraphy has been isoclinally folded as a result of the intrusion of the Dryberry Batholith.

Intense shearing and alteration occur in the rocks adjacent to Long Bay, Reed Narrows, and the Indian Village of Indian Reservation 32. This is due to the regional west-northwesterly trending Pipestone-Cameron Fault which curves southeast at Dogpaw Lake. This fault separates two diverse geologic regimes; the author is hesitant to correlate across the fault at this time. Many minor shear zones both parallel and oblique to stratigraphy are found throughout the area.

Economic Geology

Both the northern Lake of the Woods area and the Atikwa-Kakagi Lakes region, which flank the present map-area, contain many gold occurrences and prospects as well as a number of past producers. The Regina Mine within the present map-area produced over 8000 ounces of gold and 1460 ounces of silver before it finally closed. The average grade ranged from 0.15 to 0.38 ounce gold per ton (Beard and Garratt 1976). The Regina Mine is on the southern contact of the Regina Bay stock with the Snake Bay Formation, and the gold occurs in lenticular quartz veins cross-cutting the contact. Several gold showings have been described along the northern contact. The Gaudry Occurrence, found east of the Provincial Park, has diamond drillhole intersections assaying at 0.15 and 0.47 ounce gold per ton over 3 feet of pyritiferous quartz-carbonate stringers (Beard and Garratt 1976). The Bouska claims, found west of the Provincial Park boundary, contain 8 to 13 inch-wide quartz veins in the tonalite of the Regina Bay stock and a 26 inch-wide quartz vein in a northeast-trending shear zone related to feldspar porphyry dikes. Grab samples of these veins ranged from 0.01 to 0.36 ounce gold per ton, while chip samples ranged from 0.01 to 0.18 ounce gold per ton (Beard and Garratt 1976).

Several rusty, carbonatized shear zones found along the north contact of the tonalite and mafic metavolcanics were grab sampled by the field party and analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto. A rusty, sheared tonalitic dike containing about 8 percent pyrite contained 1000 parts per billion gold which is approximately 0.05 ounce gold per ton. This shear zone is located in an outcrop situated on the north side of Highway 71 at Coral Portage between Willow Bay and Long Bay. All other rusty shear zones sampled by the field party were reported by Geoscience Laboratories, Ontario Geological Survey, Toronto, to contain 0.01 ounce gold per ton.

Gold has also been reported on the Thrasher claims, which contain a fluorite showing on the north shore of Lobstick Bay (Assessment Files, Resident Geologist's Office, Kenora). Grab samples were reported to yield 0.01 and 0.08 ounce gold per ton (Beard and Garratt 1976).

Numerous electromagnetic conductors have been outlined in the map-area (Rivett and McTavish 1980; Assessment Files, Regional Geologist's Office, Kenora). These occur within both metasediments and metavolcanics. Diamond drilling on some of these anomalies has intersected pyrite- and pyrrhotite-bearing graphitic horizons, some of which contain traces of sphalerite and chalcopyrite (Assessment Files Research Office, Ontario Geological Survey, Toronto). A sample of a rusty, 60 cm wide, pyritiferous graphitic horizon, taken by the field party from an outcrop on the west side of Highway 71, 100 m north of the Berry-Dryberry Road, was analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, and contained 0.24 percent copper, 0.09 percent zinc, 15 parts per billion gold, as well as traces of lead, nickel, and molybdenum.

Gold showings occur in the Snake Bay Formation in Phillips Township, 20 km south of Sioux Narrows (Blackburn 1981). They are associated with quartz-feldspar porphyry dikes and occurs in the surrounding fractures and shears. The porphyry dikes and associated shear zones found in the present map-area should be examined for their gold potential. The contact between the Regina Bay Stock and the surrounding mafic metavolcanics has a very high potential for gold and, in particular, the areas east and west of the Sioux Narrows Provincial Park should be re-examined. In the Kakagi Lake area gold is found related to the differentiated ultramafic to mafic sills (Davies and Morin 1976). Differentiated ultramafic to mafic sills found west and north of Berry Lake should be examined for gold and platinum group mineralization. The highly sheared and altered rocks associated with the Pipestone-Cameron Fault contain gold west and south of the map-area, and there is potential for gold in this zone within the present area.

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No. 5 Geology of the Lake Nipigon Area

R.H. Sutcliffe[1] and R.C. Greenwood[1]

Introduction

This project is an investigation of the northern part of the Lake Nipigon area and a continuation of mapping started in 1981 on the southern part of the Lake Nipigon area. The area is underlain by Late Precambrian rocks of the Nipigon Plate which overlie Early Precambrian rocks of the Wabigoon Subprovince (Stockwell 1970, p.46).

During the 1982 field season an area bounded by Latitudes 49°45′N to 50°30′N and Longitudes 88°00′W to 89°00′W was mapped at a scale of 1:50 000. In addition, Late Precambrian igneous rocks in the following areas were also mapped: the area west of Armstrong, bounded by Latitudes 50°00′N to 50°30′N and Longitudes 89°00′W to 90°00′W; the Disraeli Lake-Leckie Lake area, west of Nipigon; and the Eva and Kitto Townships area, southwest of Beardmore.

Mapping during this field season has resulted in the recognition of Late Precambrian felsic subvolcanic to volcanic rocks within the Nipigon Plate, cone sheets as the feeder zones for the Logan diabase sills, and extensive quartz arenite units at the northern end of Lake Nipigon which probably correlate with the Sibley Group.

Mineral Exploration

Within the map-area, mineral exploration has primarily been in areas of Early Precambrian rocks.

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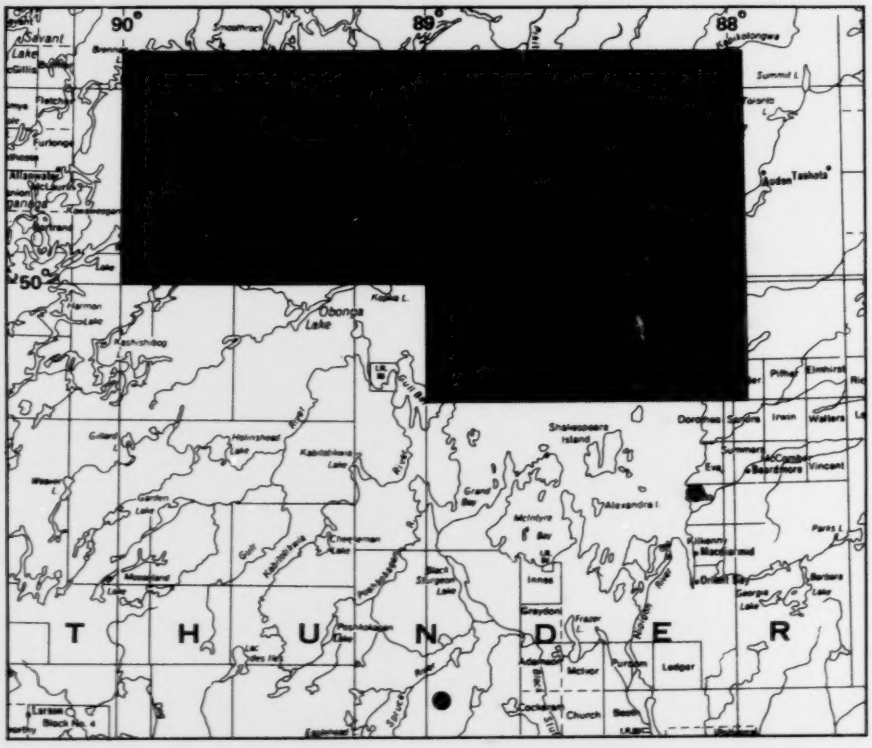

LOCATION MAP **Scale: 1:1 584 000 or 1 inch to 25 miles**

Exploration for gold and base metals has been centred on Early Precambrian supracrustal rocks. North of Lake Nipigon the Caribou Lake-Pikitigushi River metavolcanic-metasedimentary belt has been investigated since the 1930s. The most recent exploration was active from 1980 to 1982. In the Humboldt Bay area of Lake Nipigon, at the western end of the Onaman River metavolcanic-metasedimentary belt, sulphide mineralization within the metavolcanics has been investigated as recently as 1975. In 1970 and 1971 the Canadian Nickel Company Limited examined lenses of hornblendite and pyroxenite within gneissic granitoids east of Ombabika Bay of Lake Nipigon.

North of Lake Nipigon, the Zig-Zag Lake area has been explored for rare-element spodumene bearing pegmatites (Pye 1968; Breaks 1981).

General Geology

Previous mapping of Lake Nipigon was reported by Wilson (1910). Collins (1906) mapped the area northwest of Lake Nipigon as part of a survey of the area adjacent to the railway. More recent work was done by Pye (1968) in the Crescent Lake area, northeast of Lake Nipigon, and by Sage *et al.* (1974), west of Lake Nipigon.

Early Precambrian

Early Precambrian rocks within the map-area consist mainly of granitoid rocks and lesser metavolcanics and metasediments of the Wabigoon Subprovince.

The Early Precambrian rocks occur around the margin of Lake Nipigon and are intruded by the Late Precambrian Logan diabase sills and associated dikes. The Early Precambrian rocks are predominantly exposed under the Logan sills but are locally found on top of the sills.

Biotite tonalite and hornblende-biotite tonalite are the most widespread Early Precambrian lithologies in the area. The tonalite consists of several phases ranging in texture from gneissic to massive and commonly contain amphibolite and pyroxene-amphibolite enclaves. Locally, such as on the Britannia Islands of Lake Nipigon, the tonalite is discordantly intruded by mafic dikes which have subsequently been deformed and metamorphosed. Hornblende diorite is locally associated with the tonalite and is particularly common on the northeastern shore of Ombabika Bay of Lake Nipigon.

Biotite granite and granite pegmatite dikes intrude the tonalite throughout the area. East of Armstrong the biotite granite forms a late massive pluton which is intrusive into tonalite. Microcline porphyritic granodiorite forms a minor pluton peripheral to the supracrustal belt on the northeastern shore of Humboldt Bay of Lake Nipigon.

Early Precambrian metavolcanics and metasediments within the map-area were encountered mostly in the Humboldt Bay and East Bay area of Lake Nipigon and are more extensive than indicated by previous mapping. Metavolcanics and metasediments of the Caribou Lake-Pikitigushi River belt were not mapped during the present survey, except for a few outcrops along the main logging access road to the Pikitigushi Lake area. In the Humboldt Bay and East Bay area the metavolcanics consist of predominantly amphibolite facies mafic metavolcanics which display relict pillow, flow breccia, and porphyritic textures. Previously unreported intermediate fragmental metavolcanics are exposed on the eastern shore of Lake Nipigon north of Mungo Park Point. These metavolcanics consist of andesitic flow breccia and debris flow material. Minor units of metawacke and argillite are associated with the intermediate metavolcanics.

On the northeastern shore of Humboldt Bay a unit of continuing metaconglomerate with tonalite clasts occurs at what is interpreted to be the base of the supracrustal belt. Tonalite clasts in the conglomerate are similar to outcrops of tonalite on the northwestern shore of the bay.

Late Precambrian

In the area investigated, Late Precambrian rocks consist of 1) felsic subvolcanic and volcanic rocks; 2) sedimentary rocks, probably of the Sibley Group; 3) a suite of predominantly ultramafic intrusions; and 4) extensive diabase sills and dikes. The ultramafic intrusions are not shown on the accompanying map (Figure 1) since they occur south of Latitude 49°45'N.

Felsic subvolcanic and volcanic rocks have not previously been reported within the Nipigon Plate. The volcanic rocks include debris flow and ash flow deposits and appear to have originally occurred over a wide area at the northern end of the Nipigon Plate. At present they are sparsely distributed, probably due to erosion during volcanism. A quartz-feldspar porphyry to equigranular granite intrusion, centred on English Bay of Lake Nipigon, is older than the diabase sills. This intrusion is considered to be the centre of the felsic volcanism since it contains numerous inclusions of felsite and porphyry and lesser flow banded and pumiceous fragments.

In the northern part of Lake Nipigon, sedimentary rocks are present under the diabase sheet and consist predominantly of quartz arenite. Minor conglomerate is locally present at the base of the sequence. The quartz arenite reaches a maximum thickness of 25 m as indicated by sections on Humboldt Bay of Lake Nipigon and Castle Lake. The quartz arenite consists of well sorted and rounded quartz grains. Crossbeds of up to 1.8 m in thickness are a conspicuous feature of the unit, along with ripple marks. Basal conglomerate is exposed in the vicinity of English Bay and contains clasts of porphyry and felsite in a quartz arenite matrix.

During the present field season, mafic to ultramafic intrusions reported last year (Sutcliffe 1981) were examined in greater detail. The ultramafic rocks were found to be intruded by diabase sills but the relationship with the Sibley sedimentary rocks was not established. The ultramafic intrusion in Eva and Kitto Townships is a steeply dipping circular ring dike or cone sheet, 6 km in diameter,

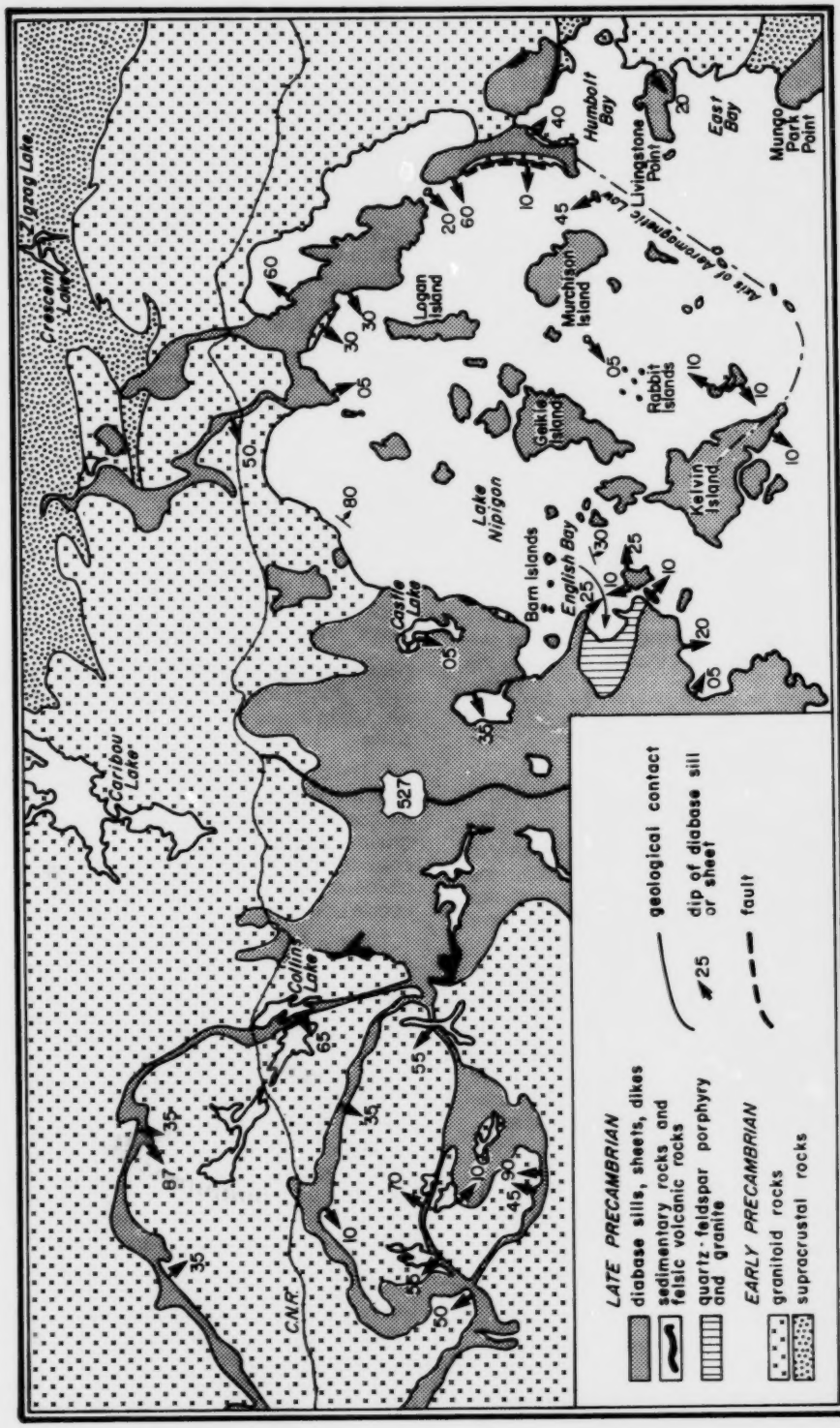

Figure 1—Simplified geology of the map-area.

which ranges in composition from olivine melagabbro to lherzolite. This structure is composite since the inner ultramafic ring is surrounded by a diabase collar. The intrusions at Leckie Lake and Disraeli Lake were found to be considerably larger than previously reported (Sutcliffe 1981). The Leckie Lake intrusion consists of a central core of clinopyroxenite to peridotite (wehrlite?), 1 to 2 km in diameter, grading outward to olivine melagabbro and gabbro. The melagabbro to gabbro appears to form a differentiated sheet and is locally layered.

Diabase sills are the most extensive rock type in the area. In the northern part of Lake Nipigon, evidence indicates that only one sill is exposed. Sections on Livingstone Point and the Barn Islands of Lake Nipigon indicate that this sill has a thickness of approximately 200 m. This sill grades, from base to top as follows: a lower chill zone, coarse ophitic diabase, to medium-grained diabase, to medium-grained diabase with coarse pegmatitic patches. Locally the medium-grained zone displays igneous layering. The upper 2 m of the sill is fine-grained to aphanitic with polygonal fractures and is locally vesicular. Minor late microgranophyre veins cross-cut the diabase sill.

Diabase cone sheets and dikes which appear to be feeders for the sills are coarser grained and have less well developed chill zones than the sills.

On the Rabbit Islands, Lake Nipigon, a possible carbonatite diatreme, 20 m wide, was found to cross-cut the diabase.

Structure

Early Precambrian

The Early Precambrian tonalites have been moderately to highly deformed. Two periods of deformation within the tonalites are indicated by the presence of amphibolite dikes which cross-cut the tonalite gneissosity and have subsequently been deformed.

The late granites are massive and have caused brittle fragmentation of the tonalites into which they were emplaced.

The presence of conglomerate with tonalite clasts at the inferred base of the Onaman River supracrustal belt at Humboldt Bay suggests that the supracrustal rocks may unconformably overlie the tonalitic rocks in this area.

Late Precambrian

The Nipigon Plate at the northern end of Lake Nipigon is a broad shallow basin. In general, the diabase sill dips gently into the centre of the lake. Steeper dips and an abrupt flexure of the sill occur along the eastern shore, along the North and South Peninsulas, and to lesser extent along the western side of the lake. These flexures in the sill are believed to reflect fault blocks in the basement extant prior to sill emplacement.

Mapping during the present survey indicates that the diabase sills were fed by cone sheets which are in the order of 30 to 50 km in diameter. This relationship was well documented west of Armstrong. Similar structures are inferred in the Macdiarmid area and possibly underneath Lake Nipigon. A circular feeder zone under Lake Nipigon is suggested by the structure of the sheet in the North and South Peninsulas area, and the continuation of this structure as an aeromagnetic anomaly.

West of Armstrong the dike forming the cone sheet has a minimum width of 100 to 150 m and dips inward at 50° to vertical. On the northern and western parts of the structure, the erosional level corresponds to the level at which the dike becomes more gently dipping and makes the transition to a sill.

Subsidence of the northern part of Lake Nipigon during emplacement of the diabase sheets may explain the preservation of a thicker Late Precambrian section in this area. Reverse faulting on the western side of the South Peninsula of Lake Nipigon in which Early Precambrian tonalites overlie Late Precambrian sediments may be related to this subsidence.

Economic Geology

Base Metals

Mineralization within the diabase sill was observed predominantly in the pegmatitic patches near the top of the sill. These zones contain sparsely disseminated chalcopyrite.

The ultramafic and associated mafic intrusions of the area are largely untested and may warrant investigation for copper, nickel, and possibly chrome and platinum group mineralization. Up to 5 percent disseminated chalcopyrite was found in a pegmatitic gabbro phase of the olivine melagabbro south of the ultramafic core of the Leckie Lake intrusion.

In the Early Precambrian rocks north of Lake Nipigon, a lens of massive pyrite with minor chalcopyrite was found immediately south of the bridge where the Pikitigushi road crosses the Pikitigushi River. The lens is over 4 m wide and has a strike length of over 50 m.

Uranium

Uranium mineralization in the Sibley Basin, documented by Franklin (1978), is associated with fractures in Early Precambrian rocks near the Early Precambrian-Late Precambrian unconformity. To the south, mineralization of this type was found in the vicinity of the Black Sturgeon Fault (Sutcliffe 1981). Exploration in 1982 by Uranerz Exploration and Mining Limited has revealed several mineralized fractures in this area, the largest of which is 40 cm wide (John Scott, Resource Geologist, Ontario Ministry of Natural Resources, Thunder Bay, personal communication, 1982). The fault on the western side of the Ombabika Peninsula and exposures of the unconformity near Humboldt Bay, Lake Nipigon, warrant investigation for this

type of mineralization. Hematized fracture zones near the contact of the English Bay porphyry and overlying sediments may also warrant investigation for uranium.

Lithophile Mineralization

Spodumene-bearing dikes with columbite-tantalite mineralization occur within the map-area, but were not examined during the survey. The economic potential of these dikes has been recently assessed by Breaks (1981).

Gold-Molybdenum

In the Collins Lake area, west of Armstrong, numerous quartz veins are present in the tonalite. Some of these veins contain molybdenite mineralization and these may also warrant investigation for gold.

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No. 6 Kirby, Fulford, and McQuesten Townships Area, District of Thunder Bay

G.P. Beakhouse[1]

Introduction

The map-area is bounded by Latitudes 49°50'21''N and 49°45'09''N and Longitudes 86°53'02''W and 87°13'08''W and covers an area of approximately 230 km^2. It includes Kirby, Fulford, and the western half of McQuesten Townships. The Town of Geraldton is located approximately 3 km south of the map-area. Highway 584 and the Greta Lake road extend through the eastern part of the map-area and much of the remaining area is accessible by 4-wheel drive vehicle on abandoned logging roads. The northern and western parts of Kirby Township are not accessible by road and lakes are too small for fixed-wing aircraft to land. Access to these areas was by helicopter.

The area has previously been mapped by MacDonald (1943). Errington and Ashmore Townships, to the south of Fulford and McQuesten Townships were mapped by Pye (1952) and Horwood and Pye (1955). Mackasey (1974) investigated the area to the west of Kirby Township.

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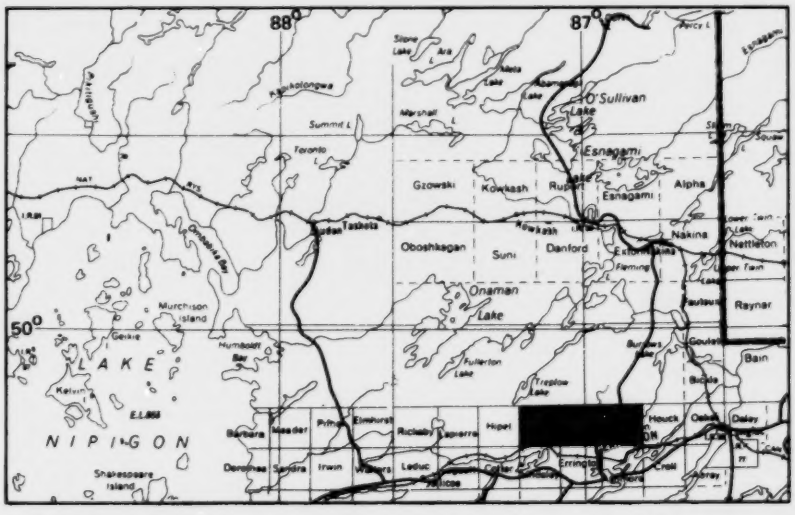
Mineral Exploration

The information on exploration activity reported here is taken from the Regional Geologist's Files, Ontario Ministry of Natural Resources, Thunder Bay, and MacDonald (1943). The main focus for exploration activity in the map-area has been gold mineralization.

A major period of exploration activity followed the discovery, in 1932, of gold mineralization on Kenogamisis Lake, approximately 5 km south of the map-area. This led to the discovery of auriferous quartz veins approximately 600 m south of the west end of Hutchison Lake. This property was successively owned by Hutchison Lake Gold Mines Limited (1935 to 1946), Maylac Gold Mines Limited (1946 to 1958), and Gulch Mines Limited (1958 to present). Development work was carried out on 4 levels. Production during the years 1946 and 1947 totaled 792



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

ounces of gold and 46 ounces of silver at an average grade of 0.52 ounce per ton gold and 0.03 ounce per ton silver. MacDonald (1943) reported that the gold occurs in narrow quartz veins and associated sulphide mineralization within "sheared and carbonatized tuffs". Limited exploration was carried out on adjacent properties during the period 1935 to 1940.

Comparatively little mineral exploration was carried out in the area from 1940 to 1960. The limited exploration carried out since 1960 has focused on ground geophysical and diamond drilling follow-up of airborne geophysical survey anomalies.

In 1961, Kateri Mining Company Limited optioned a property near Kirby Lake on which they reported the occurrence of two mineralized shear zones. They subsequently flew an airborne electromagnetic survey over much of Fulford and Kirby Townships that identified several other anomalous zones. Most of these zones occur in the vicinity of either a persistent chert-magnetite ironstone in the northern volcanic unit (see below) or near the southern volcanic unit-northern sedimentary unit contact. They reported traces of gold in pyritic zones of ironstone to the west of Kirby Lake and recommended follow-up work. Ground electromagnetic surveys of other groups was discouraging and no further work was carried out.

In 1965, Roy Barker drilled 9 diamond-drill holes in the northeastern part of McQuesten Township. Most of these drillholes encountered mafic volcanic rocks and ironstone with sub-economic zinc and copper mineralization. In the same year The Algoma Steel Corporation Limited carried out diamond drilling on a magnetically anomalous zone in the central part of McQuesten Township. This drilling encountered interlayered magnetite and clastic sedimentary rocks.

From 1969 to 1971, Canadian Nickel Company Limited carried out diamond drilling in several widely scattered parts of the map-area. Sub-economic sulphide mineralization is reported to be associated with ironstone in the vicinity of Kirby Lake, north of Grenville Lake, north of Hutchison Lake, in northeastern McQuesten Township, and east of Dionne Lake.

In 1972, Hudson Bay Exploration and Development Company Limited carried out work on two separate areas in north-central and northeastern McQuesten Township. Both of these areas lie near a laterally persistent ironstone lying in the northern part of the "greenstone belt" (discussed below). Surface geophysics located airborne electromagnetic anomalies and diamond drilling encountered massive and disseminated sulphide minerals and sulphide-bearing graphitic zones from which sub-economic zinc-copper mineralization is reported over narrow widths.

General Geology

The rocks of the area are Early Precambrian (Archean) in age and can be broadly grouped into five lithologic associations, namely: a southern metasedimentary unit, a southern metavolcanic unit, a northern metasedimentary unit, a northern metavolcanic unit, and granitic rocks (Figure 1). The contacts of these major units are accurately portrayed by MacDonald (1943).

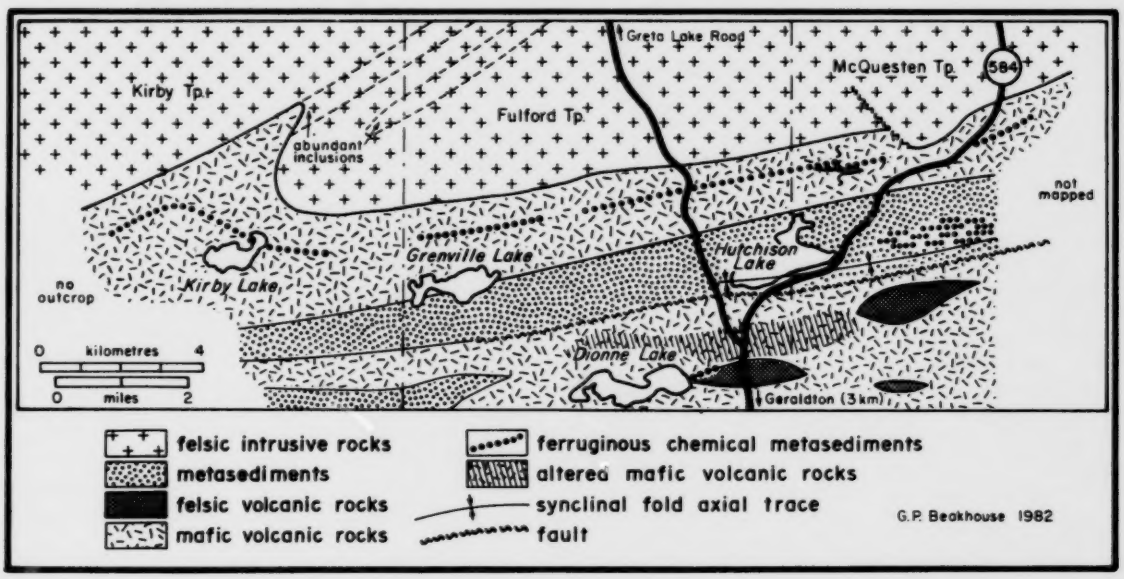


Figure 1—Geological map illustrating the general geology of Kirby, Fulford, and McQuesten Townships.

The southern metasedimentary unit is exposed in outcrops in southeastern Kirby Township and southwestern Fulford Township. The predominant rock type is polymictic conglomerate containing clasts of felsic volcanic rocks, mafic volcanic rocks, felsic plutonic rocks, chert, ferruginous chemical sedimentary rocks, mafic plutonic rocks, and vein quartz. Arkosic arenite is commonly associated with the conglomerate and occurs as massive and parallel laminated lenses. Preliminary evaluation suggests that these rocks represent deposition in an alluvial fan-fluvial environment.

The southern metavolcanic belt consists predominantly of mafic metavolcanics and associated gabbros with subordinate felsic metavolcanics and minor ferruginous chemical metasediments. The mafic volcanic rocks include both massive and pillowed varieties.

Intense alteration of mafic volcanic rocks is conspicuous south of Hutchison Lake (Figure 1). These rocks have pervasive, homogeneously distributed epidote alteration and minor epidote veining. Silicification is apparent locally. Felsic fragmental metavolcanics that range from coarse-grained tuff-breccia to ash tuff are relatively abundant in the southeastern part of the area, but the extent (and possible correlation) of these units is difficult to evaluate due to limited exposure.

Rocks of the northern metasedimentary belt outcrop in McQuesten Township and are correlated through a large area of no outcrop into Kirby Township on the basis of a single exposure in south-central Kirby Township and aeromagnetic trends (Geological Survey of Canada-Ontario Department of Mines 1974a, 1974b, 1974c, 1974d). The predominant rock type in the northern metasedimentary belt is wacke: individual beds are commonly less than 10 cm thick, scour structures and graded bedding are common, and the rocks are considered to be turbidites. Thin (<5 cm; commonly <1 cm) layers of magnetite are interlayered with the wacke in the eastern end of this belt (illustrated diagramatically in Figure 1). These magnetite layers are the source of a prominent magnetic anomaly extending in an easterly direction across the central part of McQuesten Township.

The northern metavolcanic belt consists of predominantly massive and pillowed mafic metavolcanics with subordinate fragmental felsic metavolcanics and chert-magnetite ironstone. The pervasive alteration that affected many of the mafic rocks in the southern metavolcanic belt is not evident in the northern metavolcanic belt, although in the latter, the rocks are metamorphosed to a higher grade. A major chert-magnetite unit can be traced discontinuously from central Kirby Township to northeastern McQuesten Township.

Granitic rocks, in intrusive contact with the northern metavolcanic belt, underlie approximately one-third of the map-area. Predominant phase groups, listed in order of decreasing relative age, include: equigranular, foliated tonalite-granodiorite; megacrystic granodiorite-granite; and equigranular granite. A zone trending east-northeast from a point approximately 3 km north-northeast of Kirby Lake is characterized by abundant inclusions of mafic metavolcanics and has a complex, migmatitic aspect. Elsewhere, granitic (*s.l.*) rocks tend to be relatively homogenous and contain comparatively few inclusions.

All the aforementioned rock types are cut by diabase dikes interpreted to be Proterozoic in age.

Structural Geology

The paucity of outcrops and reliable facing indicators hampers interpretation of regional structural relationships. Primary layering and foliation are generally parallel and are concordant with respect to contacts between the major lithologic units described above. Reliable top indicators in the northern metasedimentary unit indicate the presence of an isoclinal synclinal fold, the axial trace of which is asymmetrically disposed towards the southern margin of this unit. This asymmetry, together with minor structures on the southern shore of Hutchison Lake, suggest that the contact between the southern metavolcanic unit and northern metasedimentary unit is a fault.

The scant available evidence suggests that the northern and southern metavolcanic belts face towards the synclinal fold axis, but the presence of the fault and contrasting lithologies caution against treating the belt as a simple syncline. It is equally probable that the northern and southern metavolcanic units are not correlative.

The northern metavolcanic unit-northern sedimentary unit contact does not outcrop and a fault contact cannot be ruled out here. Faults have been observed or inferred along major lithologic contacts elsewhere in the Beardmore-Geraldton Belt (Pye *et al.* 1965; Mackasey 1975), and caution should be exercised in interpreting even apparently homoclinal sequences as a stratigraphic succession. Other faults, at a high angle to layering are recognized in the northern metavolcanic belt.

Economic Geology

The northern half of the Beardmore-Geraldton Belt (including Kirby, Fulford, and McQuesten Townships) has not received the attention afforded the southern half of this belt where most of the historic gold production occurred. This, in part, reflects the poor exposure in the north that discourages prospecting. The area has considerable potential for both gold and base-metal mineralization.

The most favourable area for gold mineralization is the zone of highly altered mafic volcanic rocks occurring in the southern metavolcanic belt. The only past producing gold mine in the area occurs along the northern contact of this zone, and the small, but high grade nature of the ore here suggests that further work in the area is warranted.

Many of the sulphide showings and conductive zones identified to date in the area occur in association with iron formation in the northern metavolcanic belt. Al-

though no economic mineralization has been recognized, sub-economic zinc and/or copper mineralization with traces of silver has been recognized at Kirby Lake, north of Grenville Lake, and in northeastern McQuesten Township (Regional Geologist's Files, Ontario Ministry of Natural Resources, Thunder Bay). The lateral persistence of this mineralization suggests that this may represent a favourable horizon for future exploration.

The felsic metavolcanics of the southern metavolcanic belt are poorly exposed and may be more extensive than illustrated in Figure 1. At least one of these units is spatially associated with a magnetically anomalous zone where diamond drilling has intersected a 50 m wide chert-magnetite ironstone with abundant sulphide-rich (mostly pyrite and pyrrhotite) zones (Regional Geologist's Files, Ontario Ministry of Natural Resources, Thunder Bay). The potential for economic sulphide mineralization of this type is largely untested in this area.

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No. 7 Josephine Area, District of Algoma

R.P. Sage[1]

Introduction

As part of the continuing long-range mapping program of the Wawa area (Sage 1979, 1980, 1981a, Figure 1), most of Corbiere Township, centred at Latitude 48°08'45''N and Longitude 84°36'00''W, was mapped in 1982. Parts of 4 other adjoining townships: Leclaire, Aguonie, Abotossaway, and Bird were also mapped (Figure 2). Access to Corbiere Township was by float-equipped aircraft. Those areas mapped in the remaining townships are accessible only by helicopter.

Mineral Exploration

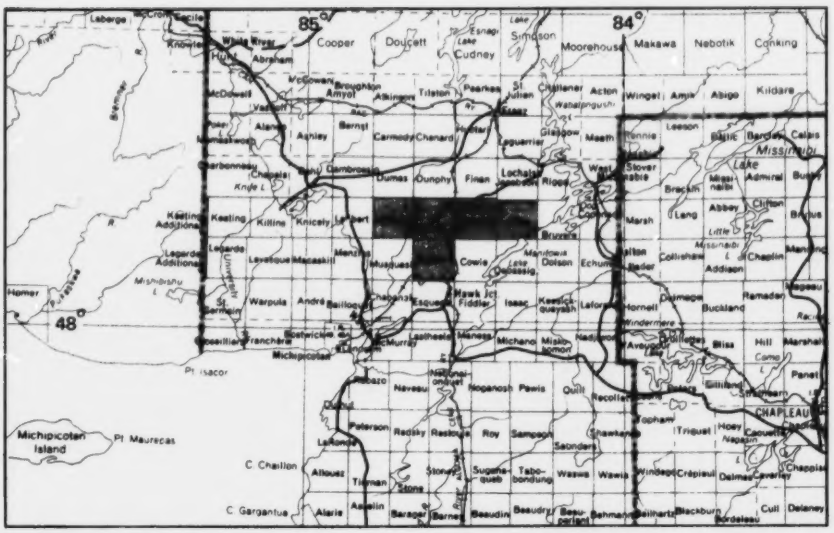
Corbiere Township

Corbiere Township has been subjected to an extensive search for mineral deposits (Sage 1981a). The iron formations within the area mapped in 1982, had been extensively tested for their iron potential by Jalore Mining Company Limited and Candela Development Company in the early 1950s. The Josephine Iron Mine produced 191 293 long tons of iron ore and contains reserves of 3 965 000 tons grading 51.65 percent iron, 14.92 percent SiO_2, and 1.88 percent Sulphur (Statistical Files, Mineral Resources Group, Ontario Ministry of Natural Resources, Toronto).

Getty Mines Limited tested the base-metal potential of the iron formation at Big Lake in the early 1970s. The Big Lake iron formation is known to contain concentrations of zinc (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)). In the southeastern corner of Corbiere Township a gold showing, locally known as the Edwards Property, occurs within supracrustal rocks marginal to the Hawk Lake Granite Complex. The gold mineralization occurs in narrow bands of sulphide facies iron formation in association with mafic and felsic metavolcanics.

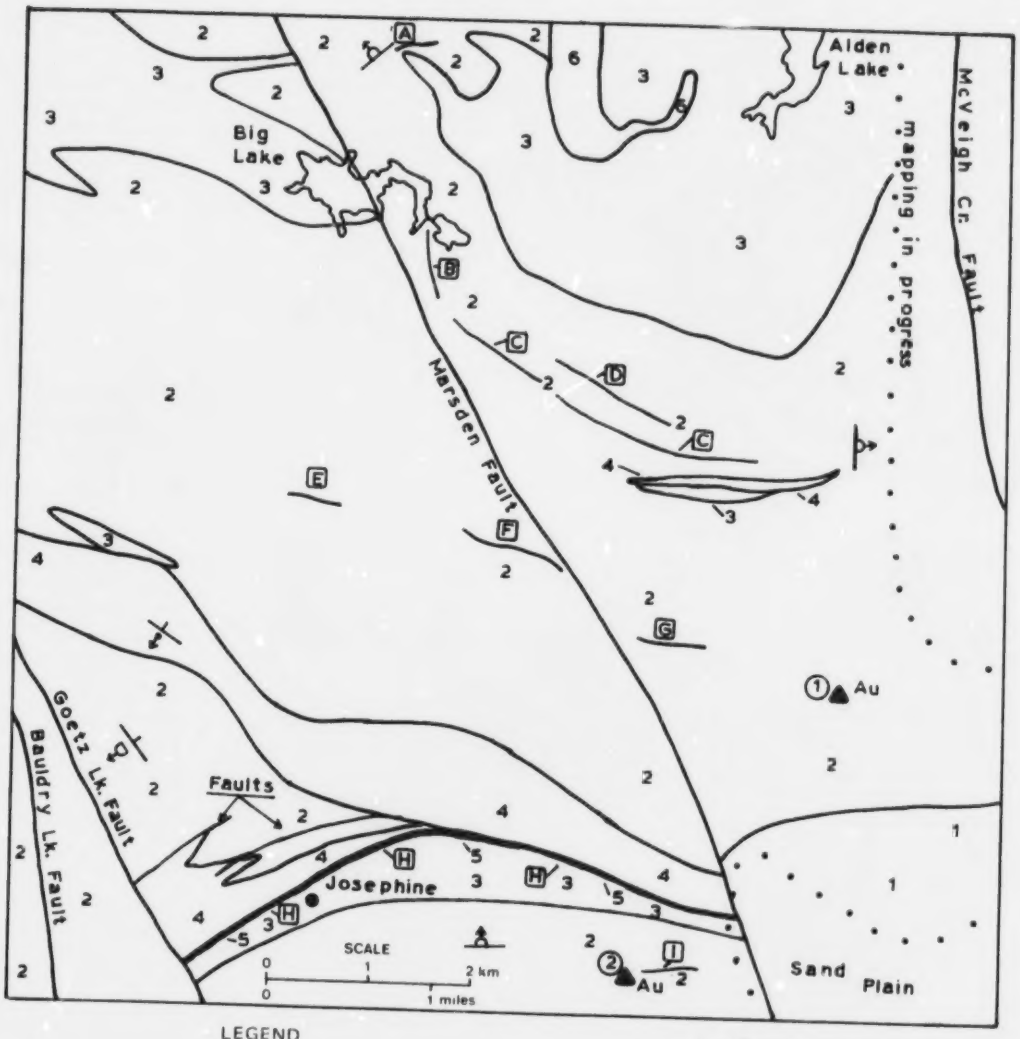
Gold occurs in a quartz vein on the Soocana-Holdsworth Property along the southern margin of the township. A zone of massive pyrite known as the Holdsworth Property occurs north of the gold showing. Diamond drilling of the pyrite showing by Algoma Ore Properties (1919) and Grasselli Chemical Company Limited (1926) indicates reserves of 1 019 273 tons grading 46.14 percent Sulphur (AFRO).

[1]Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles



LEGEND

6 Mafic intrusion
5 Iron formation
4 Metasediments
3 Intermediate to felsic metavolcanics
2 Intermediate to mafic metavolcanics
1 Granitic rocks (Hawk Lake granite complex)

Pillow elongation with facing direction indicated

Overturned

Strike and dip of metasediments with facing direction indicated

Iron Formations

A Reau-Mary lakes
B Big Lake
C Sheldon Lake
D Newric
E West Brooke
F Central Brooke
G East Brooke
H Josephine-Bartlett
I Holdworth pyrite

Gold Showings

1 Edwards Property
2 Soocana-Holdsworth Property

Figure 1—Schematic diagram of geology and mineral showings of Corbiere Township.

Leclaire Township

Within the area mapped during the past season, no base- or precious-metal occurrences are known. An iron formation present in the map-area was tested for its iron potential by Algoma Ore Properties in the mid-1950s. During the mid-1970s, Umex Incorporated completed an airborne geophysical survey of the township and did follow-up ground investigations and limited diamond-drill testing of a number of anomalies (AFRO).

Aguonie Township

Mapping during 1982 was concentrated in the southwestern corner of the township. The area was examined for its base-metal potential by Getty Mines Limited in the early 1970s. One copper showing consisting of minor concentrations of pyrite and chalcopyrite, situated along the contact of a diabase dike with its host rocks, is known to occur in the area mapped (AFRO). A zone of chloritoid alteration up to 200 m thick and exceeding 1 km in length was partially delineated but associated economic mineralization was not observed.

Abotossaway Township

Within the area mapped during 1982, significant mineralization is not known to occur.

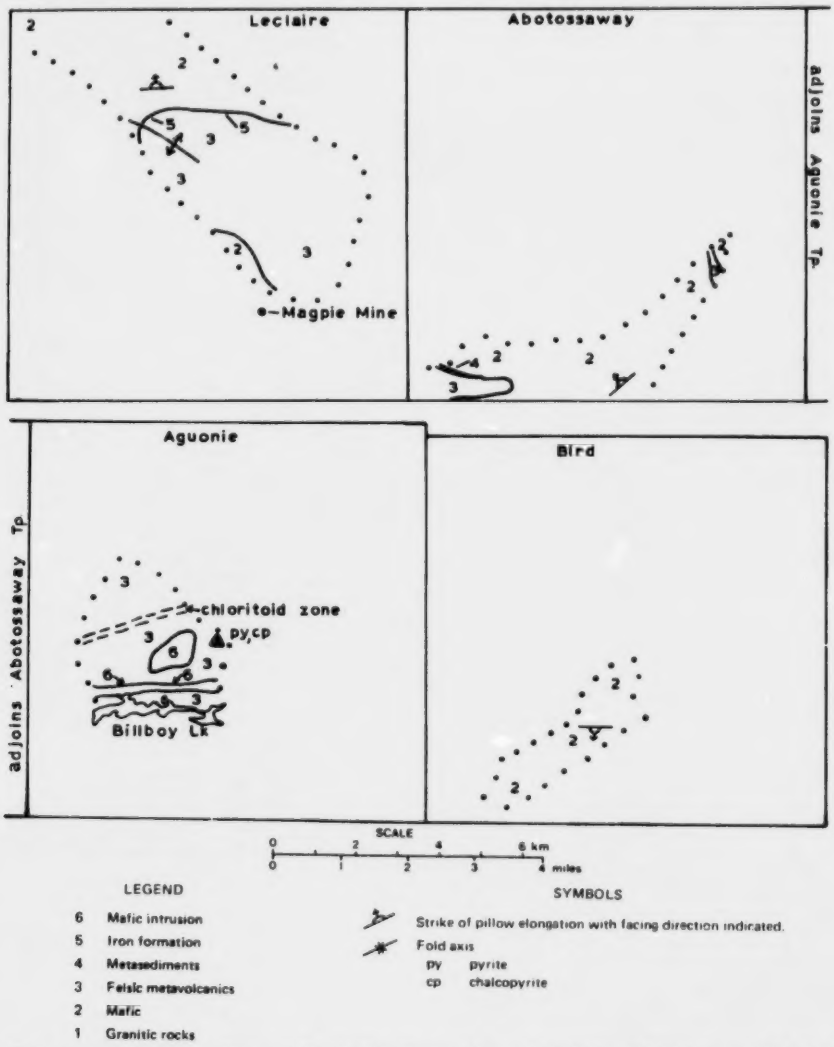


Figure 2—Schematic diagram illustrating the geology of Leclaire, Abotossaway, Aguonie, and Bird Townships.

Bird Township

Mineralization was not located during mapping and there is no record of mineralization having been previously found in the area examined this season.

General Geology

Corbiere Township

The rocks in Corbiere Township consist of mafic to intermediate and intermediate to felsic metavolcanics, mafic intrusions, clastic metasediments, and chemical metasediments including iron formation. The intermediate to felsic metavolcanics consist of tuffs, lapilli-tuffs, breccias, and flows. A major unit of intermediate to felsic metavolcanics lies beneath the Josephine-Bartlett iron formation along the southern boundary of the township. Major intermediate to felsic metavolcanic occurrences are present 3.0 km northwest of Josephine, along the northern boundary of the township, in the Big Lake area, and in the Alden Lake area. A minor amount of intermediate to felsic metavolcanics are present in the east-central part of the township. The build-up of felsic metavolcanics in the Alden Lake area suggests the presence of a former centre of volcanism at this location.

The mafic to intermediate metavolcanics consist of tuff, breccia, and massive and pillowed flows.

Minor mafic intrusions are common throughout the township, but often cannot be subdivided from other lithologies on the map due to their small size. A metagabbro intrusion of mappable size occurs immediately west of Alden Lake.

Mudstone, wacke, and rare pebble conglomerate form a distinct mappable unit approximately 0.5 km wide that strikes southeasterly from the west-central part to the southeastern corner of the township. The eastern limit of the metasediments is unknown due to the presence of a sand plain in the southeastern corner of the township.

A chemical sediment consisting of ferruginous carbonate occurs above a mafic tuff-breccia and below intermediate to felsic fragmental rocks in the Josephine area, and in the southeastern corner of the township. The unit is at least 6 to 10 m wide in the Josephine area and at least 30 m wide in the southeastern corner of the township. Intermediate to felsic fragmental rocks locally lie below the carbonate unit.

Abundant iron formation is present in the township. The major iron ranges are the Josephine-Bartlett, Newric, Cline Lake, Big Lake, Sheldon Lake, Reau-Mary, East Brooks, Central Brooks, and West Brooks. The iron formations consist of siderite, pyrite, chert, and locally minor magnetite. At Josephine, hematite was mined until the mine caved in 1946. The hematite is thought by the author to have resulted from the alteration of siderite in proximity to a north-trending fault that cuts the east-trending Josephine-Bartlett iron range.

The rocks of Corbiere Township are cut by numerous diabase dikes, most strike northwest, the remainder strike northeast.

Numerous areas of chloritoid alteration were encountered during mapping.

Leclaire Township

Mapping in Leclaire Township disclosed the presence of intermediate to felsic metavolcanics, iron formation, and mafic to intermediate metavolcanics.

The intermediate to felsic metavolcanics consist of sericite schist, tuffs, feldspar crystal tuffs, lapilli-tuffs, and coarse-grained breccias. The quartz content in the felsic metavolcanics of Leclaire Township is lower than in those found in Chabanel Township implying that the Leclaire Township felsic metavolcanics are less siliceous than those of Chabanel Township (Sage 1981a). The extensive build-up of fragmental intermediate to felsic metavolcanics in the centre of Leclaire Township suggests it was the site of a volcanic centre.

The iron formation separates the intermediate to felsic from the mafic to intermediate metavolcanics. The iron formation consists of chert, pyrite, and locally, minor concentrations of magnetite. The iron formation is known to contain significant occurrences of siderite at the former Magpie Mine (AFRO) which lies outside the area investigated this season.

The intermediate to mafic metavolcanics consist of tuffs, breccias, and massive pillowed flow units.

Numerous diabase dikes were encountered during mapping.

Abotossaway Township

Mapping was concentrated within the southern half of the township. Metavolcanics of intermediate to felsic and of mafic to intermediate composition were encountered.

The mafic to intermediate metavolcanics consist of tuff, and massive and pillowed flows.

Diabase dikes are common.

Aguonie Township

Mapping in Aguonie Township was concentrated in the southwestern corner. Intermediate to felsic metavolcanics and mafic intrusive rocks were encountered. The intermediate to felsic metavolcanics consist of sericite schist, tuff, lapilli-tuff, and coarse-grained breccia. Locally the breccia is composed of blocks exceeding 1 m in size, implying they were deposited near to a volcanic centre.

Mafic intrusive rocks occur as irregular stock-like bodies and as elongate sill-like bodies within the intermediate to felsic metavolcanics.

Within the intermediate to felsic metavolcanics, a zone of chloritoid alteration has been incompletely delineated. The zone is up to 200 m wide and exceeds 1 km in length. No mineralization was found in association with the alteration zone.

Bird Township

Mapping in Bird Township was restricted to the south-central area of the township. Only mafic to intermediate massive and pillowed flow rocks were found.

Structural Geology

Corbiere Township

In the area of Josephine, the former Josephine Mine occurs in a north-facing northeast- to east-striking volcanic sequence. Immediately north of the mine, the rocks strike west and face southwest, while northwest of Josephine, the rocks strike northwest, face southwest, and dip northeast. The northwest-trending volcanics lie in fault contact with the northeast-striking volcanic sequence.

In the east-central part of the township, limited facing data suggests that folding and faulting or both has occurred.

Along the northern boundary, limited facing data based on pillow shape suggests that the rocks face north.

Approaching the eastern boundary of the township, secondary foliations indicate an abrupt change in strike from west to north. This sharp inflection in structural trends may be related to tectonic activity along the McVeigh Creek Fault.

Numerous diabase dikes within the township commonly occupy fault or shear zones.

Leclaire Township

Facing directions in the pillowed flows located in the northwestern corner of the township indicate a north-facing sequence of rocks. While mapping of the township is far from complete, work to date would confirm the presence of an anticlinal structure, as shown on the compilation map of the area (Ayres *et al.* 1971).

Abotossaway Township

Facing direction, determined by pillow shape, within mafic to intermediate metavolcanics along the southern boundary of the township indicates a north-facing sequence in the area examined.

Aguonie Township

Facing directions were absent in the rocks mapped in this township. Dip reversals in schistosites imply the possibility of tight folding. The presence of an extensive area of intermediate to felsic metavolcanics as it appears on the geological compilation map (Ayres *et al.* 1971) has so far been confirmed, though the author suspects that folding or faulting or both have repeated parts of the section.

Bird Township

Pillow shapes in the limited area examined indicate a south-facing sequence of flow rocks.

Economic Geology

Corbiere Township

Iron formation has been the target of most exploration efforts within the township. Most occurrences of iron formation were mapped and diamond drilled during the early 1950s to investigate their iron potential (AFRO). The search was mainly for economic deposits of siderite. Most iron formation occurs stratigraphically above intermediate to felsic metavolcanics and stratigraphically below mafic to intermediate pillowed and massive flows. The iron formation at Big Lake contains anomalous zinc and has been tested by Getty Mines Limited (AFRO).

Gold occurs in a quartz vein on the Soocana-Holdsworth Property and in sulphide facies iron formation on the Edwards Property.

The rocks in Corbiere Township display pervasive carbonate alteration, contain numerous zones of chloritoid alteration, and must be considered highly favourable for base- and precious-metal mineralizaton.

Leclaire Township

The iron formation occupies the same stratigraphic position as in Corbiere Township and its iron potential has been extensively investigated. Precious-metal or base-metal mineralization is not known to occur in the area examined, but the rocks must be considered favourable for such mineralization. Metavolcanics of Leclaire Township lack the pervasive carbonate alteration and chloritoid development that characterize the rocks of Abotossaway, Corbiere, and Chabanel Townships.

Abotossaway Township

While no economic mineralization was observed in the area mapped, the rocks display pervasive carbonate alteration and must be considered highly favourable for gold and base-metal mineralization as indicated by several gold and base-metal showings within the township that lie outside the area examined.

Aguonie Township

Minor pyrite and chalcopyrite were encountered along the contact of a diabase dike with its host rocks at the eastern end of the area examined.

The extrusive rocks display moderate carbonate alteration. A chloritoid-bearing zone up to 200 m wide and exceeding 1 km in length was partially delineated. The presence of coarse fragmentals and their moderate to highly altered nature indicate a rock sequence highly favourable to base- and precious-metal mineralization.

Mineralization associated with mafic intrusions was not observed but its presence cannot be discounted.

Bird Township

Mineralization was not observed in the mafic to intermediate pillowed and massive metavolcanics, however, outcrop in this township is less than in townships to the west. The rocks warrant prospecting for sulphide mineralization along flow contacts and within pillow selvages.

Recommendations To The Prospector

The lithologies and extensive alteration zones found in the 1982 map-area suggest that the area may be highly favourable for gold and base-metal mineralization. The pervasive and widespread alteration does, however, inhibit specific target delineation based on the recognition of rock alteration alone. In general, though, if the degree of carbonate alteration is an important criteria for the presence of gold deposits (Fyon and Crocket 1981), then the pervasive carbonate alteration found in the Wawa-Josephine area suggests a highly favourable environment for gold deposits.

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No. 8 Preliminary Appraisal of Alteration of Metavolcanics in the Wawa Area, District of Algoma

R.P. Sage[1]

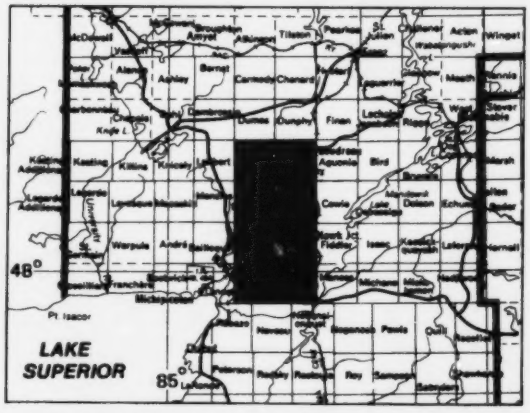
Introduction

In 1981, the author (Sage 1981b) presented a preliminary account of volcanic stratigraphy in the Wawa area. This year, after the completion of 4 mapping seasons in the Wawa area, some general comments concerning alteration are warranted. The rocks of the Wawa area are commonly highly altered and 3 types of alteration have been recognized so far. The 3 types of alteration that were identified are carbonate, chloritoid, and tourmaline.

Carbonate Alteration

Carbonate alteration is pervasive throughout Chabanel and Corbiere Townships, the southeastern corner of Musquash Township (Sage 1981a), the northwestern corner of Esquega Township (Sage 1980), and appears to extend through Abotossaway Township. The pervasive carbonate alteration affects all lithologies and displays no clear lithologic or structural control. Some of the felsic to intermediate and intermediate to mafic metavolcanics are estimated to be composed of at least 50 percent ferruginous carbonate. Small mafic intrusions often consist of 30 to 40 percent orange carbonate rhombs, of up to 1.0 mm in size, set in a chlorite matrix. There is no clear relationship between carbonate alteration and iron formation or gold and base-metal mineralization.

[1]Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.



LOCATION MAP

Scale: 1: 1 584 000 or
1 inch to 25 miles

Chloritoid Alteration

Distinct zones of chloritoid alteration are common in the Wawa area. These zones commonly contain up to 20 percent chloritoid in crystals 1 to 2 mm in size. These zones are characterized by the following features:

1. Rocks containing chloritoid are pervasively carbonatized but pervasive carbonate alteration does not necessarily mean that chloritoid is present.
2. The widespread occurrence of chloritoid suggests that the alteration that resulted in a rock composition favourable for the development of chloritoid was likely part of the original volcanic process, and not an event independent of volcanism.
3. The wide distribution of chloritoid indicates that the alteration process must represent a simple rather than complex system. The alteration process occurred at several times and in numerous places during formation of the volcanic pile.
4. Chloritoid occurs in equal amounts in both felsic to intermediate and intermediate to mafic metavolcanics, and in minor amounts in mafic intrusions. It has been identified in only one outcrop of metasediments.
5. The process that brought about the alteration of the original volcanic rocks is homogenization; felsic and mafic rocks have been altered to a similar-appearing carbonate-chloritoid rock whose original composition is difficult to determine.
6. The chloritoid crystals display a random orientation, implying that they formed post-tectonically in response to a regional metamorphic event.
7. In some fragmental units, the chloritoid shows a preferential development in the clasts over the matrix; in other outcrops, the opposite is true. Fracture-controlled chloritoid development has been observed in rare instances. In the pillowed to massive units, chloritoid commonly preferentially occurs in the pillow selvages, although outcrops displaying equal distribution

of chloritoid throughout the pillow structure are not uncommon.

8. Chloritoid is most common in rocks that form the stratigraphic footwall to the Michipicoten Iron Formation, but it has also been found in the stratigraphic hanging wall. At the Helen Iron Range (Sage 1980), the chloritoid occurs in felsic to intermediate volcanoclastic rocks directly beneath the iron formation. At the Josephine-Bartlett Iron Range, which is the eastern stratigraphic extension of the Helen Iron Range, the chloritoid occurs in pillowed and massive intermediate to mafic flows that lie statigraphically below the felsic to intermediate metavolcanics.
9. Although chloritoid zones are commonly associated with iron formations, particularly in the carbonate and sulphide facies, zones of chloritoid development without any associated iron formation are common.
10. While the long dimension of a chloritoid zone conforms to stratigraphy, the zone can encompass many individual flow units and is thus not confined to a specific unit. In addition, chloritoid-bearing pipe-like bodies that cross-cut the stratigraphy, which could be interpreted as feeders or pathways for the fluids causing the alteration, have not been recognized.

Tourmaline Alteration

In the area west and southwest of West Andre Lake (Sage 1981a), the massive and pillowed mafic metavolcanics display an unusual tourmaline alteration. The tourmaline distribution is erratic and is not confined to a distinct unit. Black tourmaline crystals approaching 3 cm in length have been observed and tourmaline may comprise an estimated 10 to 15 percent of a given rock outcrop. The tourmaline preferentially occurs in pillow selvages, but it also occurs disseminated throughout the pillow structures. In some outcrops, fractures control the distribution of tourmaline. The tourmaline occurs as interlocking crystals projecting away from the fractures, and, in the pillowed flows, as radiating clusters, isolated crystals, and interlocking masses.

Mapping during the 1982 field season extended the tourmaline zone southwestward, normal to stratigraphy, from the area outlined in 1981. Mineralization has not been observed in association with this style of alteration. Tourmaline alteration is accompanied by moderate to strong carbonate alteration.

Recommendations to the Prospector

The lithologies and extensive alteration zones found in the 1982 map-area suggest that the area may be highly favourable for gold and base-metal mineralization. The pervasive and widespread alteration does, however, inhibit specific target delineation based on the recognition of rock alteration alone. In general, though, if the degree of carbonate alteration is an important criteria for the presence of gold deposits (Fyon and Crocket 1981), then the pervasive carbonate alteration found in the Wawa-Josephine area suggests a highly favourable environment for gold deposits.

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No. 9 Batchawana Synoptic Project

E.C. Grunsky[1]

Introduction

A synoptic study of the Batchawana area has continued into its second year in order to integrate and summarize existing geological information. The area is bounded by Latitudes 45°56'00''N to 47°30'00''N and Longitudes 83°30'00''W to 84°50'00''W. Geological mapping at detailed and reconnaissance scales is being carried out in areas previously unmapped to resolve discrepancies between existing geological maps. Field data, economic geology data, laboratory data, and thin section data is being compiled in order to create a computer database which will allow for an integrated system of stored geological data for investigative and archival purposes.

The synoptic study will focus on the stratigraphy, chemistry, ages, and structure of the Early Precambrian (Archean) supracrustal assemblage, and the structure, ages, and tectonic framework of the surrounding felsic intrusive rocks. A review of the known mineral occurrences, deposits, and mines will be carried out to aid future mineral assessment and mineral exploration in the area. In conjunction with this study, determinations of the ages (U-Pb Zircon) of the Early Precambrian (Archean) supracrustal sequence and the surrounding felsic intrusive rocks will be done by the Royal Ontario Museum, Toronto. A study of the paleomagnetism of the diabase dike swarm(s) that intrude the map-area will be done at the University of Toronto (see Ernst, this volume).

A computer-based format for recording field geological data was adopted for use during the 1982 field season. It was used for both detailed and reconnaissance-scale mapping. The computer-based mapping format is being developed following Lambert and Reesor (1974), and forms part of the framework for development of the database. The format used for the 1982 field season is in the design stage and will be further developed and

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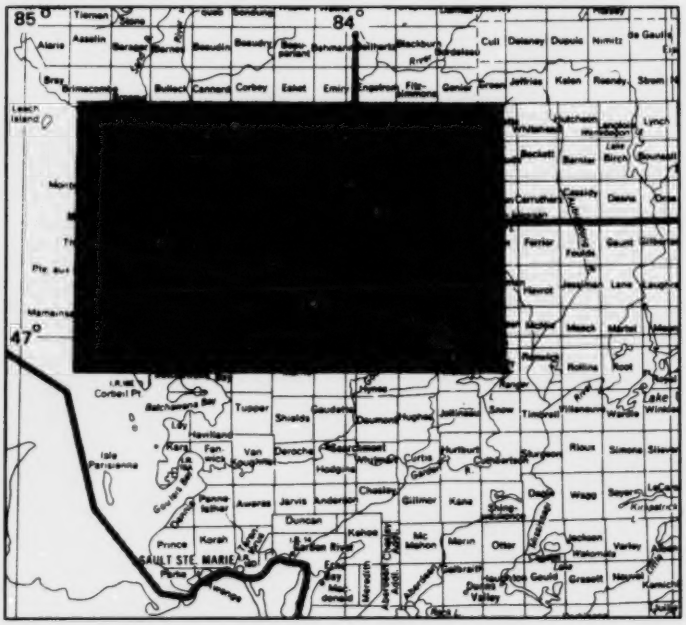

LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

modified over a period of time with the aid of other users (see Stott, this volume).

A compilation of existing geological maps and reports has been previously reported (Grunsky 1981b). This summary contains information that was gathered during the past field season.

General Geology

The Early Precambrian (Archean) metavolcanic-metasedimentary assemblage has been deformed, metamorphosed, faulted, and intruded by felsic intrusive rocks. The area was covered in part, by sedimentary rocks of the Huronian Supergroup. Keweenawan volcanics overlie the Early Precambrian (Archean) supracrustal and plutonic rocks at the western edge of the area. Figure 1 provides a generalized geological map of the area.

An aerial (helicopter) reconnaissance geological mapping program was carried out in the northern and eastern regions of the map-area. The northern and northeastern part of the area is chiefly underlain by migmatitic rocks composed of quartz-plagioclase-biotite gneisses and schists. Varying amounts of assimilation of pre-existing material has occurred throughout the northern and northeastern parts of the area. North of the Montreal River, a broad west-trending band of migmatite that has been less assimilated than other rocks in the area occurs.

Felsic plutonic areas adjacent to the eastern edge of the supracrustal sequence (Wlasy and Bracci Townships) appear to be composed of massive granodiorite. The areas to the south and southeast of the Cowie Lake area are underlain by massive felsic plutonic rocks of quartz monzonite, granodiorite, and trondhjemite compositions.

Investigation of migmatitic rocks in the Montreal River area revealed schollen and schlieren of magnetite-chert ironstone within a quartz-plagioclase neosome and biotite gneiss paleosome. This occurrence of ironstone may be the western extension of the magnetite ironstone that occurs to the east in the Grey Owl Lake area. This ironstone may be stratigraphically equivalent to the lowermost ironstone that occurs near the margins of the belt (Cowie Lake, Rotunda Lake, Schembri Township), and may thus place a northern limit on the supracrustal rocks. Migmatized supracrustal rocks occur north of this area but the association with supracrustal rocks in the Batchawana area is unclear.

Detailed mapping in the Lunkie-Hynes Townships area has outlined the southern extension of the supracrustal rocks. These rocks are principally felsic tuffs, and ash tuffs with minor mafic metavolcanics. The termination of the supracrustal rocks in this area is characterized by an intrusive boundary marked by a xenolith zone and tonalitic areas marginal to a massive granodiorite intrusion.

Reconnaissance mapping was carried out in the Meenach Lake area of Davieaux and Desbiens Townships. In this area a sequence of mafic metavolcanics is overlain by wackes and siltstones. The mafic metavolcanics predominate in the area west of Meenach Lake. East of Meenach Lake the main rock types are metasediments that extend northward into the Quintet Lakes area (Siragusa 1981). Contact relationships between the metavolcanics and metasediments are obscured by two large faults that transect the area. Eastward towards Gavor Lake (Desbiens Township), the metasedimentary domain is more extensive than had been previously interpreted (Giblin and Leahy 1977).

The Batchawana area is cut by inumerable diabase dikes. Most of these dikes are of unknown age and in the past have been tentatively assigned to a Late Precambrian age (Giblin and Leahy 1977). Massive porphyritic and non-porphyritic types are found. Many dikes grade from porphyritic to non-porphyritic types along strike. Many dikes bifurcate and join up with other dikes. The dikes trend 135° to 140° with a vertical to subvertical dip. Most of the dikes appear to be quartz tholeiites, although a few dikes are olivine-bearing. All of the dikes cut the Early Precambrian (Archean) supracrustal and plutonic rocks, and 1 dike has been observed cutting across a Huronian sedimentary outlier (Grunsky and Arengi 1978). The presence of quartz tholeiite and olivine-bearing diabase dikes indicate there were at least 2 periods of diabase dike emplacement and in all probability there were more. Samples of diabase dikes have been collected throughout the area for petrographic and chemical analysis. Determination of the major oxide and trace element chemistry of these dikes may help to distinguish different diabase dike suites. Several samples have been selected for paleomagnetic studies (see Ernst, this volume). One sample of diabase dike was in addition to being sampled for paleomagnetic studies, was also sampled for U-Pb Zircon age dating.

Samples were collected at 16 locations for U-Pb Zircon age dating. The rock types sampled include felsic metavolcanics, massive "late" felsic intrusive rocks (Grey Owl Lake, Mongoose Lake, Griffin Lake stocks), and the felsic intrusive rocks that surround the supracrustal belt.

Structural Geology

The structure of the supracrustal sequence consists of a west-trending syncline that extends from Cow River to the Grey Owl Lake pluton where it merges with a north-northwesterly trending syncline from the Cowie Lake area (Figure 1). The structure in the Cowie Lake area was previously reported (Grunsky 1980, 1981b) to be an overturned monocline but may in fact be a northeasterly dipping north-northwest-trending syncline. This new interpretation is supported by the facing of pillowed flows in the Dismal Lake area (Siragusa 1978) and graded beds from wackes in the Wart Lake area.

The supracrustal succession in the western part of the belt has been complexly folded into several synclinal and anticlinal structures as indicated by opposing facings in pillowed metavolcanics (Giblin and Armburst

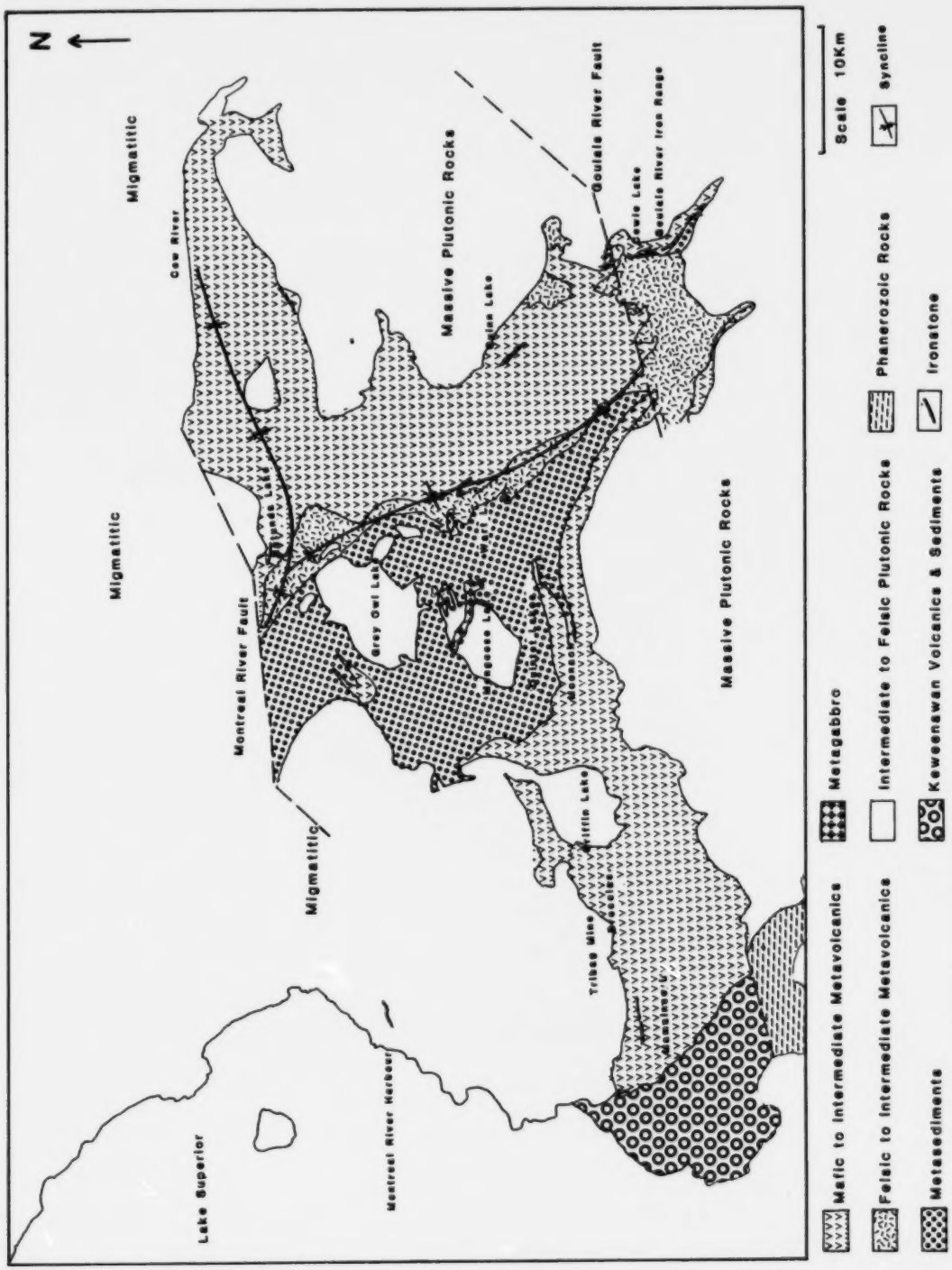

Figure 1—Generalized geological map of the Batchawana area.

1973). If the magnetite-chert ironstone in the migmatite of the Montreal River Harbour area can be correlated to the lowermost ironstone near the margins of the belt, then the migmatite between Pancake Lake and the Montreal River may be one assimilated limb of a broad synclinal structure of which only the southern part (Mamainse Lake area) has been preserved. The structure of the western part of the supracrustal sequence is not yet clearly understood. The synclines developed in the eastern part of the supracrustal sequence may be structures developed by the emplacement of two large intrusive bodies situated east and south of the supracrustal rocks. The development of these intrusive rocks from pre-existing volcanic centres (L.S. Jensen, Geologist, Ontario Geological Survey, Toronto, Ontario, personal communication, 1982) would allow the development of the arcuate merging synclines as regions where metavolcanics and metasediments accumulated. Theses synclines would be preserved between major volcanic domains that were subsequently transformed into major intrusive centres.

Economic Geology

The Batchawana area has had two significant copper producers, the Tribag and the Coppercorp Mines, both post-Keweenawan deposits. Neither of these mines has exhausted their ore supplies and favourable conditions could make them operable again. A significant iron ore deposit, the Goulais River Iron Range at Cowie Lake, is an Early Precambrian (Archean) magnetite-chert ironstone with current estimated reserves at 30 480 000 tonnes (Canadian Mines Handbook 1975 to 1976) currently owned by The Algoma Steel Corporation Limited. A brief discussion of the Post-Keweenawan deposits can be found in Grunsky (1981b).

The Batchawana area has received little exploration attention in the past. Known precious- and base-metal deposits are small or currently uneconomic. The Algoma Central Railway carried out a major exploration program on their lands in the early 1960s but nothing of significance was found or reported. Several base-metal occurrences containing copper, some zinc, silver, and traces of gold have been reported in the Grey Owl Lake area and southeastward into the Cowie Lake area. Many of these occurrences are found close to the mafic metavolcanic-felsic metavolcanic boundaries (Cowie Lake, Quinn Lake areas); the felsic metavolcanic-metasedimentary boundaries; and the facies transition zone between felsic metavolcanics and metasediments (Grey Owl Lake area). The proposed north-northwesterly trending syncline from the Cowie Lake to the Grey Owl Lake area may aid exploration efforts focused on tracing out the continuity of these favourable stratigraphic horizons and may help to uncover previously unknown deposits or help to follow known occurrences along strike.

Mineral occurrences related to the felsic intrusive rocks should not be overlooked. A quartz vein at the contact of Grey Owl Lake stock contains 0.54 ounce per ton silver and trace gold (Grunsky 1981a).

Several anomalous radioactive zones both of large low grade regional extent and small concentrated vein types occur throughout the northern part of the map-area.

Mineral Exploration

Mineral exploration for precious and base metals has occurred throughout the map-area during the past year. Exploration for base metals has been carried out in the Hanes Lake area in Gapp Township, and in the area west of Meenach Lake (Davieaux Township). Re-examination of an old gold occurrence (New Hiawatha Gold Mines) has occurred. Several companies prospected the Early Precambrian (Archean) supracrustal sequence during the 1982 field season.

Dekalb Mining Corporation submitted a report in January 1982 (Resident Geologist's Office, Ontario Ministry of Natural Resources, Sault Ste. Marie) outlining the results of their exploration work at the Tribag Mine. Their report indicates 3 breccia pipes (Breton, east, and west breccias) are mineralized with varying amounts of chalcopyrite, molybdenite, sphalerite, galena, scheelite, as well as gold and silver. The mineralization is structurally zoned and controlled by domal fractures within the pipes. The Breton breccia pipe was considered for open pit mining but has since been rejected due to poor market conditions. The west breccia zone was examined and 28 000 tons of 0.87 percent WO_3 and 40 000 tons of 2.0 percent copper were outlined as reserves. Tonnage estimates for the other breccias are not available. Dekalb Mining Corporation has not been active on the property since 1981.

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No. 10 Ile Parisienne and Rudderhead Point Areas, District of Algoma

P.E. Giblin[1]

Introduction

The map-areas cover the shoreline area of Lake Superior between Goulais Bay and Batchawana Bay, approximately 30 km northwest of Sault Ste. Marie, and also nearby islands in Lake Superior.

The Ile Parisienne map-area is bounded by Latitudes 46°37′30″N and 46°45′00″N, and Longitudes 84°30′00″W and 84°45′00″W. It adjoins the Goulais River area (described elsewhere in this volume) on the west, includes parts of Dennis and Kars Townships on the mainland, and Ile Parisienne in Lake Superior.

The Rudderhead Point area adjoins the Ile Parisienne area on the north. It is bounded by Latitudes 46°45′00″N and 46°52′30″N, and Longitudes 84°30′00″W and 84°45′00″W. The area includes the northern part of Kars Township and most of Ley Township on the mainland, the southwestern part of Batchawana Island, Maple Island, and the Sandy Islands in Lake Superior.

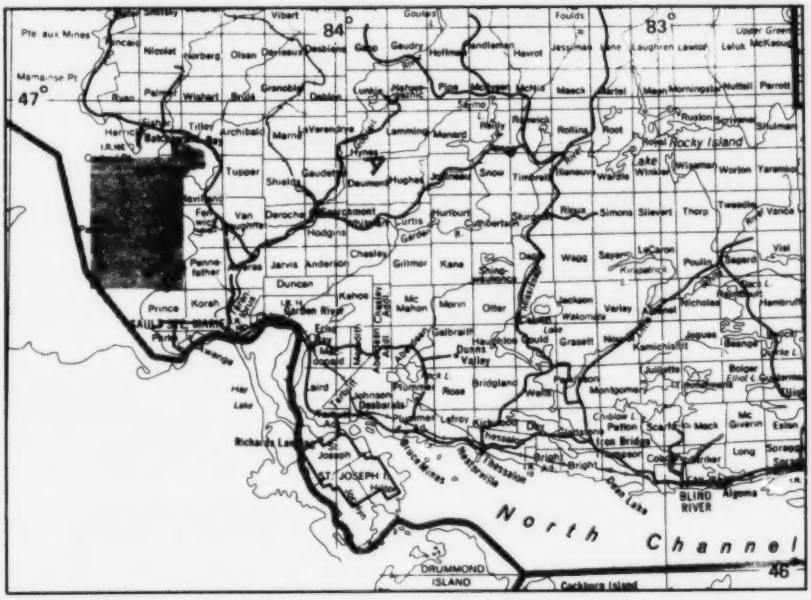
In addition, mapping was extended to cover parts of the areas adjoining east and northeast of the Rudderhead Point area, specifically to complete the mapping of Batchawana Bay and Goulais Bay in Ley, Kars, and Havilland Townships.

For convenience of discussion, the several map-areas will be referred to collectively as a single area.

Mineral Exploration

A manganese occurence located in Ley Township, east of Horseshoe Bay and immediately east of the area mapped, was explored in 1942 (Resident Geologist's

[1]Resident Geologist, Ministry of Natural Resources, Sudbury, Ontario.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

Files, Ontario Ministry of Natural Resources, Sault Ste. Marie).

General Geology

The area is underlain by Precambrian supracrustal and plutonic rocks and by supracrustal rocks of probable Paleozoic age. Most of the mainland area and the islands in Lake Superior are covered by unconsolidated Pleistocene and Recent deposits. Bedrock exposures are largely confined to coastal zones.

Early Precambrian (Archean) felsic plutonic and migmatitic rocks are presumed to underlie the high ground in Dennis Township, in the southeastern corner of the area. Although there are no exposures within the area, similar terrain to the east is known to be underlain by these rocks.

Clastic sedimentary rocks of the Lorrain Formation of the Huronian Supergroup are exposed in Kars and Havilland Townships, near the northern shore of Goulais Bay. They consist of white quartzite, pebbly quartzite, and pebble conglomerate, and are found in small hills forming outliers surrounded by sedimentary rocks of the Jacobsville Formation.

Middle Keweenawan basalts with minor intercalated conglomerates are exposed in Ley Township, in the central section of the east shore of Horseshoe Bay and the adjacent inland area. A felsite dike has intruded the basalts.

The basalts are overlain by cobble and boulder conglomerates and very minor interbedded sandstones. These rocks are exposed on the southeastern shore of Horseshoe Bay and the adjacent inland area. Clasts in the conglomerates are predominantly sub-rounded to sub-angular, and consist of Early Precambrian granitic rocks and mafic metavolcanics, Lorrain Formation quartzite, siltstone probably derived from the Huronian Gowganda Formation, Middle Keweenawan basalt and felsite, and diabase and quartz of uncertain age. The coarse-grained sand matrix is weathered grey in colour on coastal outcrops but in inland exposures, where it is less weathered, it is commonly dark red-brown. Carbonate is present sporadically in the matrix. Distinct bedding is absent. In some outcrops there appears to be imbrication of elongate clasts.

Neither the base nor the top of the conglomerate unit is exposed and its thickness is uncertain. It appears to have a minimum thickness of about 70 m, and an approximate maximum thickness of about 215 m.

Correlation of the conglomerate unit is uncertain. McConnell (1927) considered it to be the basal portion of what was then termed the Lake Superior sandstone, now termed the Jacobsville Formation. However, the lithologic characteristics of the conglomerate and interbedded sandstones resemble those of Middle Keweenawan sedimentary rocks in the nearby Mamainse Point area, with the exception of the presence here of abundant clasts of Huronian rocks. The presence of these clasts is not suprising in view of the proximity of outcrop areas of Huronian rocks. The writer tentatively correlates the conglomerate unit with the Middle Keweenawan.

Clastic sedimentary rocks of the Jacobsville Formation, of probable Cambrian age, underlie most of the mainland region and all of the islands in Lake Superior.

They consist largely of feldspathic arenites with very subordinate intercalated siltstones and shales. Minor conglomerate is present on the flanks of Lorrain Formation outliers in Kars Township. The rocks are predominantly red to red-brown in colour, and exhibit abundant mottling with white circular spots and irregular white blotches and streaks. A few beds are grey to white in colour with pink and red mottling.

The sandstones are most commonly thin bedded, but bed thicknesses range from very thin to thick. Rounded, isolated, pebbles of quartz, chert, basalt, quartzite, and granite are sporadically present. Angular to sub-angular chips of red and grey shale are common in some beds. Ripple marks and trough crossbedding are common.

Paleocurrent measurements show that the direction of the sediment transport in the Jacobsville Formation was dominantly westward. In the lower part of the formation, exposed on Batchawana Island and on the mainland, paleocurrents flowed dominantly to the southwest. It is noteworthy that a few outcrops exhibit widely divergent paleocurrent directions. Within the upper exposed part of the formation, as seen on Ile Parisienne and the Sandy Islands, paleocurrents flowed predominantly west to northwest.

Thin cobble conglomerate and coarse sandstone, the latter sometimes in the form of clastic dikes, overlie Lorrain Formation rocks on the flanks of the outliers noted earlier.

The Nipissing stage of the Great Lakes development is represented by wave-cut terraces, beach gravels, and lacustrine sands. Mapping of the Quaternary deposits in the mainland parts of the area by W.R. Cowan (unpublished map, Ontario Geological Survey) shows a zone of beach and near-shore gravels generally lying at and above the 198 m elevation contour. Cowan's work in the Sault Ste. Marie area showed the Nipissing phase to be represented by a well developed wave-cut bluff with its base at an elevation of about 197 m above sea level (Cowan 1978). A well developed wave-cut bluff with its base at the same elevation is present in Dennis Township, in this area, and in the adjacent Goulais River map-area.

In general, below the 198 m contour lacustrine sands are commonly present, and above the 213 m contour, clay and swamp deposits are common.

A thin boulder pavement overlies the Jacobsville Formation sandstone on Steamboat Island (the small island north of the Sandy Islands) and on both North Sandy Island and South Sandy Island.

Structural Geology

Bedding in the Lorrain Formation strikes east and dips 45° to 70° north.

The Keweenawan basalt flows strike N05°W to N15°E and dip west at 20° to 35°. The overlying conglomerate and interbedded sandstone unit appears to strike about N10°W and dip west at about 15°.

The abundant crossbedding in the Jacobsville Formation often makes measurements of general attitude difficult. The strike of the bedding is predominantly northwest and the dip is predominantly west, at angles ranging from 05° to 30°. A few dips to the east, at angles of 05°, were observed.

Anomalous attitudes are present in the Jacobsville Formation at the northeastern corner of Horseshoe Bay, immediately north of the exposures of Keweenawan basalt. The contact is covered, but within a few metres north of it, sandstones are exposed. They strike N50°W to N90°W, and closer to the basalts they dip vertically. The dips flatten progressively to the north, decreasing to 20° about 900 m north of the contact. Evidently this locality is the "area of highly disturbed sandstone", attributed to faulting by Du Bois (1962). D.J. Russell (Geologist, Ontario Geological Survey, Toronto, personal communication, 1982) has pointed out that this zone appears to be on strike with a fault he recently recognized on the eastern shore of Batchawana Bay, on the north side of which the Jacobsville sedimentary rocks have been downfaulted to lie in contact with Early Precambrian migmatitic rocks.

The present survey has shed some light on a second correlation problem within the area. Earlier workers had considered that the red sandstones all belonged to the same formation, which was generally termed the Lake Superior sandstone (now Jacobsville Formation) and considered to be Cambrian in age (e.g. McConnell 1927).

A new interpretation was introduced by Hamblin (1958) who suggested that the sandstones along the coast between Goulais and Batchawana Bays belong to the Late Precambrian Freda Formation, and that an angular unconformity existed between them and the Jacobsville Formation rocks on Ile Parisienne. As evidence he stated that the coastal rocks between Goulais Point and Batchawana Bay "consistently dip 10 to 12 degrees to the north, whereas exposures of the Jacobsville Formation found inland and on the west side of Parisian Island are essentially horizontal".

The present survey has shown that the coastal rocks do not dip consistently northward. They do in fact dip predominantly westward, conformably with the rocks exposed inland and on Ile Parisienne. Northward dips were found in only two places. In one of these, the northward dip can readily be attributed to crossbedding, and the other is possibly attributable to faulting, as noted above.

Rocks of the Jacobsville Formation exposed inland and on Ile Parisienne do not dip "essentially horizontally" as stated by Hamblin, but dip consistently west at angles of 05° to 30°.

The writer concludes that there is no convincing basis for Hamblin's interpretation of the existence of Freda Formation rocks in the area, and that the red sedimentary rocks all belong to the Jacobsville Formation.

Economic Geology

The well sorted Nipissing-phase beach gravels have been used for road construction, and will probably be used in the future for local construction purposes. They are generally found at, and slightly above, the 197 m contour.

A small pit has been opened in Jacobsville sandstone on the western side of the Goulais Bay-Horseshoe Bay road, about 1.2 km north of Highway 552. The stone appears to have been removed for use as flagstone.

The Keweenawan basalts are host to a small manganese occurrence east of the area mapped. Exploration work on the occurrence has proven to be disappointing. Similar rocks contained the copper deposits of the Coppercorp Mine, and may have potential for the discovery of copper deposits. Their extent, however, is small (McConnell 1927; Giblin, Leahy, and Robertson 1979).

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No. 11 Goulais River Area, District of Algoma

P.E. Giblin[1]

Introduction

The centre of the area is located about 8 km north of the City of Sault Ste. Marie. It includes parts of Aweres, Dennis, Fenwick, Pennefather, and Vankoughnet Townships; and is bounded by Latitudes 46°37′30″N and 46°45′00″N, and Longitudes 84°15′00″W and 84°30′00″W.

Mineral Exploration

Exploration work in the area has been carried out principally in search for copper deposits, and has been concentrated largely in Aweres Township.

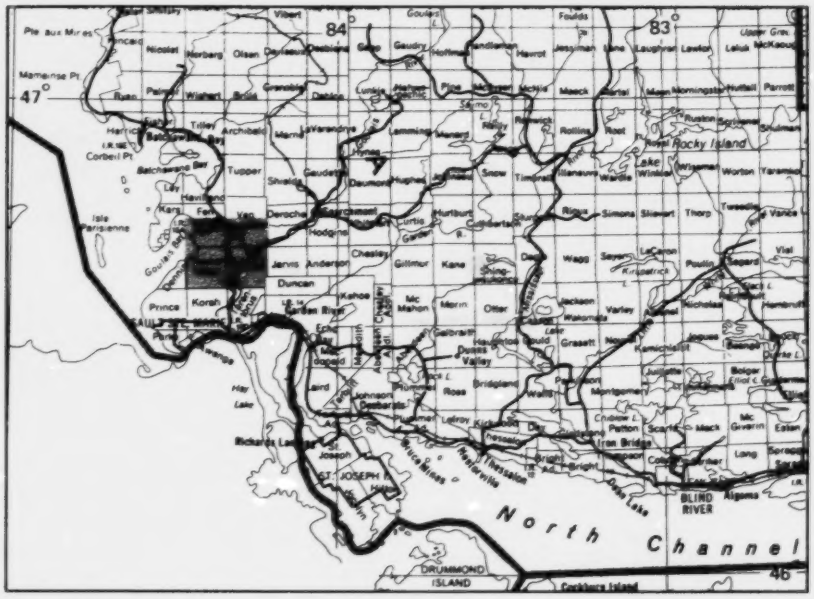
In 1907, the Hillman Copper Company Limited trenched and sunk a shaft to a depth of about 16 m on a copper occurrence located in the southwestern part of the township. Detta Minerals Limited drilled 3 holes during 1955 and 1956, having a total length of 377.3 m. In 1961, H. Johnson drilled 1 hole 41.1 m deep.

Most exploration work has been concentrated on, and near, the Nystedt Occurrence, located in the northeastern part of Aweres Township near the junction of Highways 552 and 556. In 1965 and 1966, Kennco Explorations (Canada) Limited conducted geological, geochemical, electromagnetic, and induced polarization surveys; trenching; and drilled 18 holes having a total length of 909.8 m. The occurrence was further explored by Copperville Mining Corporation during 1970 and 1971, when 10 holes with a total length of 1170.6 m were drilled.

In 1968, Texas Gulf Sulphur Company Incorporated drilled a hole in the southeastern part of Fenwick Township to a depth of 447.3 m.

Tri-Bridge Mines Limited held a property southwest of the Nystedt Occurrence in 1971. Magnetometer and electromagnetic surveys were completed, and 9 holes having a total length of 716.1 m were drilled.

[1]Resident Geologist, Ontario Ministry of Natural Resources, Sudbury, Ontario.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

General Geology

The area is underlain by Early Precambrian (Archean) supracrustal and plutonic rocks, Proterozoic supracrustal and intrusive rocks, and supracrustal rocks of probable Paleozoic age. Unconsolidated Pleistocene and Recent deposits cover large parts of the map-area.

Early Precambrian (Archean) mafic metavolcanics with minor intercalated metasediments underlie a small area in the extreme northeastern corner of the area. Early Precambrian (Archean) felsic plutonic and migmatitic rocks underlie most of the southern half of the area, and consist of quartz monzonite, trondhjemite, syenite, diorite, and migmatites with highly variable proportions of included mafic gneiss.

Supracrustal rocks of the Huronian Supergroup occur in the southeastern corner of the map-area, and in a narrow strip along the northern border.

In the southeastern corner, most of the area south of Highway 556 is underlain by rocks of the Thessalon and Aweres Formations, believed to be correlative with the Elliot Lake Group, and by rocks of the Gowganda Formation of the Cobalt Group.

The Thessalon Formation rocks are basalt, and are exposed only at the eastern border of the map-area, on the Algoma Central Railway right-of-way.

The Aweres Formation overlies the Thessalon Formation disconformably and is exposed throughout most of the area south of Highway 556. It consists predominantly of intercalated grey feldspathic sandstones and clast-supported and matrix-supported polymictic conglomerates, and very minor siltstones.

The sandstones are dominantly feldspathic wackes, less commonly lithic and quartzose wackes, and are commonly pebble-bearing. Quartzose arenites are present in minor amounts. The sandstones are most commonly thick bedded and massive. Some beds exhibit trough or planar crossbedding. Ripple marks are rare.

The basal part of the formation consists of dark-coloured very thickly bedded and massive, boulder and cobble conglomerates which contain much basaltic debris, almost certainly derived from the underlying Thessalon Formation. There is a rapid upward decrease in the amount of volcanic debris, and most of the Aweres Formation consists of light grey sandstones, and pebble and cobble conglomerates containing well rounded to rounded, pink granitic clasts but little or no volcanic debris.

Subordinate clast types are grey granitic rocks, quartz, mafic volcanic rocks, mafic metavolcanics, metasediments, and diabase.

The volcanic debris occurs as rounded to subangular clasts, and small, angular, often triangular-shaped fragments that are now chlorite, and appear to represent pyroclastic debris.

The stratigraphic position of the Aweres Formation has long been uncertain. It, the underlying volcanic rocks, and a still lower formation which lies outside the map-area are isolated from the main Huronian belt. Because of the problems inherent in correlating across this gap McConnell (1926) grouped the 3 formations as the "Soo Series" which he considered to be of lower Huronian age. In recent years, correlation of the volcanic rocks with the Thessalon Formation of the Elliot Lake Group has become generally accepted.

Rocks of the Gowganda Formation overlie those of the Aweres Formation in a small area straddling Highway 556 near the eastern border of the map-area. They consist of siltstone, feldspathic sandstone, and polymictic boulder and cobble conglomerates.

The largest area underlain by Cobalt Group rocks is in the northeastern part of the map-area, east of Highway 17 and generally north of the Goulais River, where both the Gowganda and Lorrain Formations are represented. The Gowganda Formation rocks are similar to those described above. The Lorrain Formation consists of white massive quartzite that is commonly brecciated and cut by narrow quartz veins.

Diabase dikes of uncertain age have intruded the Early Precambrian (Archean) and Huronian rocks. Lamprophyre dikes are intrusive into the Early Precambrian (Archean) felsic plutonic rocks and some diabase dikes. Felsite dikes, of probable Keweenawan age, cut the Aweres Formation and nearby Early Precambrian (Archean) felsic plutonic rocks.

Clastic sedimentary rocks of the Jacobsville Formation, of probable Cambrian age, underlie most of the valley of Goulais River. They are also exposed southward in a narrow fringe along the shore of Lake Superior and in offshore reefs. Thinly bedded mottled red and white feldspathic arenites predominate. Thinly laminated to very thinly bedded reddish shales and siltstones are interbedded with the sandstones. Trough crossbedding and ripple marks are common. Drilling in Fenwick Township shows that, in this area at least, the basal part of the Jacobsville Formation consists of clast-supported polymictic pebble conglomerate overlying a thin regolith developed on Early Precambrian (Archean) granitic gneiss.

An unusual conglomerate, tentatively correlated with the Jacobsville Formation, occurs in the northeastern part of the map-area, east of the Goulais River. Well rounded cobbles and pebbles of quartzite (probably derived from the Lorrain Formation) occur in a coarse sand matrix. The clasts have been fractured on a fine scale: many show step faulting, and fractures in the clasts have commonly been filled by the matrix.

Glacial striae commonly strike between S20°W and S30°E. Topographically high parts of the area, generally underlain by Precambrian rocks, are commonly covered by a thin mantle of till. Topographically low parts of the area generally correspond with areas underlain by the Jacobsville Formation, and are covered by thick glaciolacustrine, glaciofluvial, and alluvial deposits of gravel, sand, silt, and organic debris. Abandoned beaches are present on the flanks of the Goulais River valley. Near the

northern border of the area an abandoned boulder beach lies at an elevation of about 243 m. A strongly developed Nipissing bluff, with its base at an elevation of about 198 m above sea level, occurs in the southwestern corner of the area in Dennis Township. Numerous off-shore sand bars or abandoned beaches are present in the Goulais River valley west of Highway 17. Drilling in the valley has shown the unconsolidated materials are as much as 108 m thick.

Recent deposits consist of swamp, lake, and alluvial deposits. The Goulais River is building an extensive delta into Lake Superior.

Structural Geology

Foliation in the Early Precambrian (Archean) metavolcanics strikes about N60°W, and dips vertically to steeply north. Foliation within the Early Precambrian (Archean) felsic plutonic and migmatitic rocks is irregular in attitude, but most commonly strikes northeast. Dips range from flatly north to vertical to flatly south.

Rocks of the Thessalon and Aweres Formations generally strike northwest, dip west, and face west. The only east dips observed in the Aweres Formation occur in the western part of its outcrop area very close to a major fault, and may be due to drag on the fault. Many faults appear to be present, disrupting stratigraphic continuity. The upper part of the formation is gently folded about a synclinal axis which strikes east through Aweres Lake.

The Aweres Formation overlies the Thessalon Formation disconformably, but the contact now is evidently the locus of a fault.

Contacts of the Aweres Formation with the Early Precambrian (Archean) rocks are all fault contacts, the Aweres Formation having been down-faulted, on vertical to near-vertical faults, relative to the Early Precambrian (Archean) rocks. A nonconformable contact reported by McConnell (1926) was searched for but not found.

Bedding in the Gowganda Formation strikes easterly, dips gently north, and faces north. In the southeastern corner of the map-area the Gowganda Formation overlies the Aweres Formation with angular unconformity, and is in fault contact with Early Precambrian (Archean) rocks. In the northern part of the area the Gowganda Formation is in fault contact with Early Precambrian (Archean) metavolcanics, and with the Lorrain and Jacobsville Formations.

The outcrop area of the Lorrain Formation strikes easterly, parallel to the strike of the nearby Gowganda Formation. Bedding was not observed. The rocks are commonly brecciated, and in place foliated. The foliation strikes N75°W and dips 70°N. The Lorrain Formation appears to be separated from adjacent formations by northwest-trending faults. Bedding in the Jacobsville Formation was observed only near the base of the formation, and the observed attitudes reflect the irregular topography of the basement upon which the Jacobsville sediments were deposited. Strikes vary widely, but dips are consistently away from the current high ground and towards the basin of Lake Superior and into the Goulais River valley.

A prominent fault-line scarp on the northern side of the Goulais River valley marks the contact between the Jacobsville Formation and the Gowganda Formation. The fault, named herein the Vankoughnet Fault, strikes about N75°W and appears to dip steeply north. Although no parallel fault has yet been found on the largely drift-covered southern flank of the valley, it is possible that this portion of the Goulais River valley is an easterly trending graben, in which rocks of the Jacobsville Formation have been down-faulted relative to the adjacent rock units.

Several other major faults are present. Near the southern border of the area, the Aweres Fault (Frarey 1978) strikes approximately N75°W across most of the map-area. The fault, reflected by a prominent valley, cuts Early Precambrian (Archean) felsic plutonic and migmatitic rocks, and has in turn been intruded by a diabase dike which is the locus of some copper mineralization.

The Aweres Formation appears to be everywhere bounded by faults. On the northern edge of its exposure area it is bounded by a major fault, named herein the Island Lake Fault, which is closely followed by Highway 556 and the northern shores of Lower Island Lake and Upper Island Lake. The Island Lake Fault strikes about N45°E and appears to dip vertically. It is offset by a set of faults which strike N35°W and dip steeply east.

The Early Precambrian (Archean) felsic plutonic and migmatitic rocks adjacent to the Island Lake Fault exhibit strong cataclasis and the development of much chlorite. The chlorite occurs as narrow zones of chlorite schist and as disseminated grains within the rocks. The altered zone, although irregular in detail, generally strikes parallel to the fault. It has been traced over a strike length of about 4 km and over a maximum width of about 1 km. The altered zone contains the Nystedt copper Occurrence.

The diabase dikes, which are earlier than the Island Lake Fault, most commonly strike northwest, from about N50°W to about N80°W, and dip vertically. Felsite dikes most commonly strike N25°W to north and dip vertically.

Economic Geology

Copper and uranium mineralization occur in the area. Gravel and rubble from brecciated rocks in a fault zone, have been used for road construction. Peat moss and peat are present.

Copper mineralization is present in 2 settings:

1. Chalcopyrite occurs in quartz veins that are found in and adjacent to diabase dikes (e.g. Hillman Occurrence).
2. Chalcopyrite occurs in small quartz veins and disseminated in brecciated granitic, syenitic, and dioritic rocks (e.g. Nystedt Occurrence).

At the Hillman Occurrence, located 2 km west of Highway 17 in the southwestern corner of Aweres Township, chalcopyrite occurs as stringers and irregular blebs in a quartz vein. The vein lies in a sheared diabase dike that intruded the Aweres Fault zone. At the principal showing, chip samples taken by others assayed 1.33 percent copper, nil gold; and 0.83 percent copper, 0.005 ounce per ton gold, both over widths of 2.6 m (Resident Geologist's Files, Ontario Ministry of Natural Resources, Sault Ste. Marie). A grab sample of well-mineralized vein material collected by the author, and assayed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, contained 5.67 percent copper, 0.01 ounce per ton gold, and 0.11 ounce per ton silver. Drilling by Detta Minerals Limited traced the vein over a strike length of 165 m and showed it to have an average width of 3.3 m. Very sparse chalcopyrite mineralization was found in the vein intersections.

Traces of malachite and chalcopyrite were found by the author in quartz veinlets in the sheared diabase about 800 m east of the Hillman Occurrence. Traces of chalcopyrite were also found in quartz-carbonate veinlets in and adjacent to several other diabase dikes. These occurrences are all very small and very low grade.

The Nystedt Occurrence is located in Aweres Township, 500 m northwest of the junction of Highways 552 and 556. Chalcopyrite, accompanied by specularite and minor pyrite, occurs in quartz veins and veinlets, and disseminated in brecciated, chloritized granitic, syenitic, and dioritic rocks. The vein mineralization is found in fractures having varied attitudes. Available data do not present any summary of grading or tonnage. Similar mineralization has been explored by trenching at a locality 500 m northeast of the main occurrence. The epigenetic mineralization has been controlled by brecciation of the host rocks. The zone of brecciation and chloritization is, as noted earlier, related to the Island Lake Fault zone. Prospecting for similar deposits should be concentrated upon the zone of cataclastic chloritized granitic rock north of the Island Lake Fault.

Very low-grade uranium mineralization is present in the northeastern part of the area, in Section 26, Vankoughnet Township. It has been described briefly by Giblin and Leahy (1979). Three parallel radioactive zones occur in brecciated Lorrain Formation quartzite. The zones range in thickness from 5 to 15 cm, and occur across a horizontal width of about 12 m. They can be traced on strike for about 6 m. Samples from the weathered radioactive material assayed 40 to 87 parts per million U_3O_8, with less than 10 parts per million ThO_2. The zones strike N70°W and dip 35°N.

The occurrence lies within the Vankoughnet Fault zone. Although the assay values are too low to be of economic importance themselves (despite the fact that leaching has probably removed some uranium), the occurrence demonstrates the presence of uranium mineralization within and probably controlled by a major fault. Other sections of the Vankoughnet Fault may warrant prospecting for uranium occurrences.

Gravel has been obtained from pits in both outwash and beach deposits. Brecciated rock from the Vankoughnet Fault zone has been used for road construction.

Peat and peat moss occur in Fenwick and Vankoughnet Townships near Highway 17. The occurrence has been described by Graham (1976).

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No. 12 Brunswick Township, District of Sudbury

G.M. Siragusa[1]

Introduction

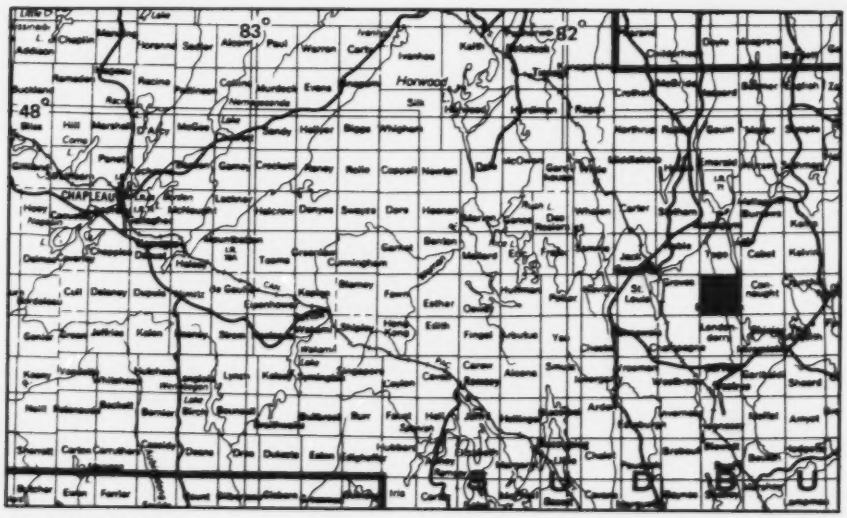
Brunswick Township was mapped in May and June of 1982 as part of a continuing study of the Swayze Belt. The township adjoins the east boundary of the Pensyl Lake area (Siragusa 1981) and is bounded by Latitudes 47°34′56″N and 47°40′07″N, and Longitudes 81°27′40″W and 81°35′20″W.

The north-northwest-trending Nabakwasi River bisects and gives access to most parts of Brunswick Township. Due to prominent rapids and waterfalls on the Nabakwasi River in the centre of the township, two routes can be followed to the river. Access to the northern half of the township is by a gravel road which connects Highway 144 with the northern bank of the Minisinakwa River in Mattagami Township, and then by a 14 km long waterway which includes segments of the Minisinakwa and Nabakwasi Rivers. It is 18 km from the access point on the Minisinakwa River to the Town of Gogama via Highway 144. Access to the southern half of Brunswick Township is by a waterway which starts at the southern tip of Nabakwasi Lake in Miramichi Township. The lake can be reached from Highway 560 via a 6 km long bush road. It is 68 km from Nabakwasi Lake to Gogama via this road, Highway 560, and Highway 144. The waterway includes Nabakwasi Lake and a segment of the Nabakwasi River, for a total of about 15 km. Hanover Lake in the southwestern corner of the township is accessible by bush plane.

[1]Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto, Ontario.

Mineral Exploration

With the exception of the recent staking of 81 claims, the writer found no field evidence or assessment records of previous exploration activity in Brunswick Township. The recent claims consist of 3 separate groups of 30, 36, and 15 unpatented contiguous claims located in the northwestern, central, and east-central parts of the township, respectively. In the fall of 1981 these claims were transferred to Canadian Nickel Company Limited. No record of exploration work on these properties has been submitted by the company as of the time of writing.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

General Geology

A narrow, generally west-trending belt of Early Precambrian (Archean) supracrustal rocks underlies the central part of Brunswick Township. It has a maximum and minimum width of 3500 and 1300 m, respectively. This belt is the eastern extension of the supracrustal belt in the adjacent Pensyl Lake area (Siragusa 1981). About two-thirds of Brunswick Township is underlain by predominantly potassic granitic rocks, including coarse porphyritic phases and locally, pegmatite. The supracrustal and granitic rocks are intruded by north-northwest-trending diabase dikes.

The supracrustal rocks are generally poorly exposed. They were metamorphosed to greenschist rank. A subvertical foliation is well developed in these rocks. Exposures of relatively undeformed mafic metavolcanics and conglomeratic metasediments are present along segments of the Nabakwasi River, and along the eastern shore of Mattagami Lake. In most cases, however, the outcrops of supracrustal rocks are schists that contain variable proportions of chlorite, biotite, hornblende, muscovite, and carbonates, and in which the evidence of primary features has been completely obliterated by deformation. The conglomeratic rocks consist of variable volumes of dominantly granitoid clasts up to 1.5 m in size, embedded in a fine- to coarse-grained matrix which varies in composition from essentially chloritic to quartzofeldspathic. Shearing of conglomerate with a low clast density and chloritic matrix, results in a green-grey schist which can be virtually indistinguishable from a mafic metavolcanic rock. Similarly, shearing of conglomerate containing a large volume of clasts, or with a quartzofeldspathic matrix, produces a white muscovite schist which closely resembles a felsic metavolcanic rock. For mapping purposes, the following empirical criterion was adopted to distinguish metavolcanics from metasediments: outcrops of schist uniformly chloritic along and across strike were mapped as mafic metavolcanics, and outcrops showing significant compositional variations along or across strike were mapped as metasediments. In southwestern Brunswick Township and at one locality in the adjacent Pensyl Lake area (Siragusa 1981) outcrops which resemble conglomerate were found, on close examination, to have in fact originated from progressive deformation of syntectonic granitic intrusions. In one section of the outcrop, foliated rocks contain granitic clasts which are chaotically distributed parallel to the foliation. In adjacent sections across the strike of foliation, the chaotic arrangement gives place to discrete quasi-collinear arrays of lenticular clasts which clearly originated from boudinaging of formerly continuous concordant intrusive sheets of granite.

Three north-northwest-trending major faults dissect the area. Two of these, the Hanover Lake and Mattagami Lake Faults, cross the southwestern and northeastern corners of the township, respectively. The course of the Nabakwasi River crosses the middle of the township, defining the third fault, the Nabakwasi River Fault. All these faults have left-lateral movement, with the east side of each fault displaced to the north, relative to the west side. The estimated horizontal displacements, along the Hanover Lake and Nabakwasi River Faults are 1400 and 1700 m, respectively; the displacement along the Mattagami Lake Fault is undetermined but is probably greater than 1100 m.

The west half of the belt, delimited by the Hanover Lake and Nabakwasi River Faults, comprises a tight west-trending syncline that has been further deformed by north-trending cross-folding. This part of the belt consists almost entirely of metasediments and minor mafic metavolcanic units in parts of the northern limb of the structure. Parts of northwestern Brunswick Township are underlain by an isolated west-trending body of recrystallized mafic metavolcanics which, prior to deformation and emplacement of granitic intrusions, was probably connected with the mafic metavolcanic units just mentioned. This body is very poorly exposed, consists of medium- to coarse-grained amphibolite, and contains local xenoliths of basalt and magnetite ironstone; it has pronounced aeromagnetic relief and an inferred maximum length of 5600 m and a width of 900 m. The eastern half of the belt is delimited by the Nabakwasi River and Mattagami Lake Faults, and has approximate maximum and minimum widths of 3500 and 2500 m, respectively. It consists of equal amounts of mafic metavolcanic and metasedimentary units which have been folded into a tight west-trending syncline. This structure is simpler than that of the western half of the belt (i.e. west of the Nabakwasi River Fault), as it was not affected to any significant extent by north-trending cross-folding.

Economic Geology

One outcrop of north-trending magnetite ironstone associated with mafic metavolcanics of greenschist facies rank was located approximately 3500 m east and 1100 m south of the northeastern corner of Brunswick Township. These mafic metavolcanics are part of a less metamorphosed domain that lies along the eastern margin of the previously mentioned amphibolite body that underlies the northwestern part of the township. These metavolcanics and ironstone are characterized by an aeromagnetic peak of 3100 gammas. Another aeromagnetic peak of 3200 gammas occurs in an area of no exposure 2100 m west of the ironstone outcrop. The whole amphibolite body may warrant geophysical investigation and/or test drilling. A north-trending and east-dipping quartz vein which has an average thickness and exposed strike-length of approximately 35 cm and 15 m, respectively, was noted on the eastern bank of the Nabakwasi River about 2200 m south of the northern boundary of the township. The vein is locally stained with reddish-purple hematite. It may warrant prospecting for gold as it occurs in metasediments adjacent to the Nabakwasi River Fault.

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No. 13 Garson Township, District of Sudbury

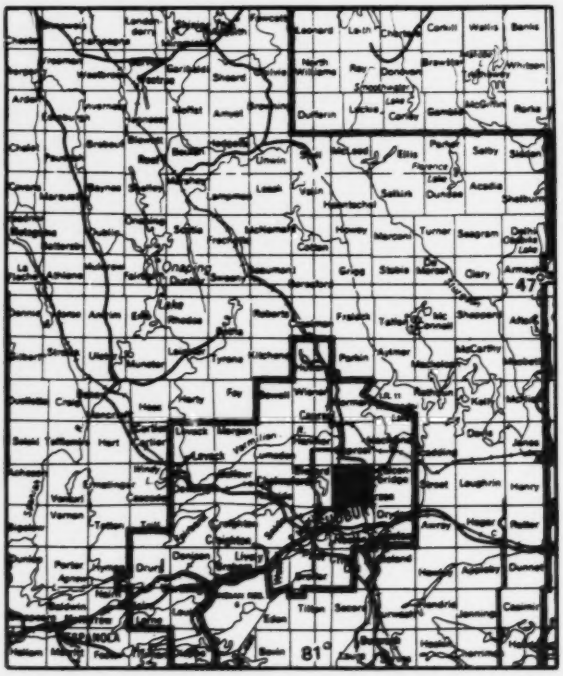
P.E. Giblin[1]

Introduction

The map-area lies within the Regional Municipality of Sudbury, adjoining the northeastern border of the City of Sudbury. It is bounded, approximately, by Latitudes 46°32′N and 46°37′N, and Longitudes 80°49′W and 80°57′W.

Mapping was carried out over most of the western third of the township at a scale of 1:15 840 (1 inch to ¼ mile).

[1]Resident Geologist, Ontario Ministry of Natural Resources, Sudbury, Ontario.



LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

Mineral Exploration

Nickel, copper, and precious metals are produced from the Garson Mine, owned by Inco Limited. The mine has been in more or less continuous production since 1908. It is temporarily closed due to the current shutdown of Inco's operations.

The Kirkwood Mine, also owned by Inco Limited, produced nickel, copper, and precious metals from 1970 to 1976.

The area has been explored intermittently since the discovery of nickel-copper mineralization near Sudbury in 1883. Exploration work has been concentrated on the southern, outer edge of the Sudbury Igneous Complex, with which the nickel ores are associated. The contact zone has been mapped in detail by mining companies, and considerable diamond drilling has been carried out. In 1982 Inco Limited carried out detailed geological mapping in the western part of the township.

Gravel is produced from pits in the eastern part of the area, while sand is produced for use as smelter flux and back-fill from large pits in the southern part of the area.

General Geology

The geology of Garson Township was mapped by the Geological Survey of Canada in the 1930s at a scale of 1:63 360 (1 inch to 1 mile) as part of a regional mapping program in the Sudbury area (Cooke 1947). Subsequent published maps have been essentially compilation maps at the same scale (Thomson 1956; Card 1969). These maps illustrate the distribution of the major rock types.

Rocks of the area are all of Middle to Late Precambrian (Proterozoic) age and are subdivided into 3 major groups: rocks of the Huronian Supergroup that underlie the southern third of the area; rocks of the Whitewater Group underlying a narrow strip in the northern part of the area; and those of the Sudbury Igneous Complex, underlying the central half of the township. A fourth, minor group includes small granitic dikes of uncertain age, and Middle to Late Precambrian diabase dikes.

The Huronian Supergroup is represented by rocks of the Elliot Lake and Hough Lake Groups. The Elliot Lake Group in this area consists, in ascending stratigraphic order, of mafic metavolcanics of the Elsie Mountain Formation, intercalated metasediments (principally wackes,

with minor arenites and pebble conglomerates) and mafic metavolcanics of the Stobie Formation; felsic metavolcanics of the Copper Cliff Formation; and siltstones and arenites of the McKim Formation. Within the area mapped, the overlying Hough Lake Group is represented only by rocks of the Ramsay Lake Formation, which consist of conglomeratic sandstones, sandstones, and siltstones. Sudbury Breccia and shatter cones are commonly present in the Huronian rocks.

Rocks of the Onaping Formation of the Whitewater Group consist of a thin basal quartzite breccia, succeeded by coarse fragmental rocks of the Grey Onaping member, and by fine fragmental rocks of the Black Onaping member. The stratigraphic terminology used herein is that of Stevenson (1961) and Peredery (1972). Although there is a general upward fining through the Grey to Black Onaping members, it is not uniform. In at least one locality, coarse fragmental rocks overlie fine fragmental rocks of the Grey Onaping. In another locality, there appears to be intercalation of at least 3 zones of quartzite breccia with Grey Onaping fragmental rocks. In one case, the fragmental Grey Onaping grades upward, through increasing content of quartzite fragments, into quartzite breccia.

The Sudbury Igneous Complex (often referred to as the Sudbury Nickel Irruptive) consists of a southern, lower zone of norite, a thick central zone of gabbro, and a wide zone of granophyre on the north. It is intrusive into rocks of the Elsie Mountain Formation on the south, and into rocks of the Onaping Formation on the north.

Narrow granitic to aplitic dikes intrude into the norite member of the Sudbury Igneous Complex, the Elsie Mountain metavolcanics, and metasediments of the Stobie Formation. Their age is unknown.

Late Precambrian olivine diabase dikes of the Sudbury 'swarm' intrude into rocks of the Huronian Supergroup, the Whitewater Group, and the Sudbury Igneous Complex.

Pleistocene glaciation scoured the bedrock surface, and abundant striae and glacial grooving indicate that the predominant direction of ice flow was about S25°W. Subsequent glaciofluvial and glaciolacustrine deposits of gravel, sand, and silt cover much of the southern and eastern parts of the township.

Structural Geology

The major rock units strike east to northeast within the area mapped.

Rocks of the Elliot Lake and Hough Lake Groups face south. Their dips range from steeply south, to vertical, to steeply north in those places where the beds have been overturned. Contacts of units within the Onaping Formation are rarely visible. The few that have been observed strike southeast and dip 50° to 70°S.

Insufficient work has been carried out to date to comment on the dip of members of the Sudbury Igneous Complex. East of the area mapped, in the vicinity of the Garson Mine, the southern margin of the Complex is known to dip vertically to steeply south (Yates 1948).

All of the above formations and rocks of the Sudbury Igneous Complex exhibit a regional foliation, to a greater or lesser degree. The foliation strikes east to southeast and generally dips steeply south. Several major shear zones also strike east to southeast and generally dip steeply south.

The late olivine diabase dikes occupy fractures which commonly strike approximately S75°E.

Economic Geology

The nickel-copper-precious metal deposits are associated with the outer, lower, margin of the Sudbury Igneous Complex.

Sand and gravel are derived from deltaic glaciofluvial deposits that cover much of the eastern and southern parts of the township. The distribution of these deposits is shown by Burwasser (1979).

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No. 14 Structural and Chemical Studies of Mafic Dike Swarms in Northern Ontario

Richard E. Ernst[1]

Introduction

The central part of the Superior Province of northern Ontario is host to a large number of predominantly post-Early Precambrian mafic dikes (Figure 1) which have been separated into a number of swarms using paleomagnetic, radiometric, and petrologic criteria (Fahrig 1972; Gates and Hurley 1973; Card *et al.* 1981; Ernst 1981; Pike 1982). Detailed analyses of the structural and chemical characteristics of these dikes may provide additional information that will help in determining such features as the direction of magma flow, the depth of dike exposure, and the magnitude and orientation of post-intrusive regional tilting to as close as 5° (Halls 1982). The present work provides the first testing of some of the techniques proposed by Halls (1982) and should increase our understanding of the Middle to Late Precambrian (Proterozoic) tectonic and magmatic history of the central part of the Superior Province.

Field Work

The field work involved two procedures:

1. measurement of dips, thickness, phenocryst concentration, and degree of alteration of mainly north- to north-northwest-trending dikes of probably 2.6 Ga age, as well as a few northwest-trending Sudbury (1.25 Ga) dikes, and northeast-trending Abitibi (1.1 Ga) and Preissac (2.15 Ga) dikes. The data were collected mostly from along main highways within a large area extending from Latitudes 47°00′N to 49°00′N and Longitudes 80°00′W to 85°00′W.
2. collection of samples from several of these dikes to test the feasibility of determining flow direction from the orientation of elongate phenocrysts, and to determine the variation in geochemistry due to chemical differentiation during flow. The goal is to test whether the flow has a horizontal component as discussed by Halls (1982), and to map any variation in flow inclination on the scale of a single dike and of a swarm. Evidence of horizontal magma movement from dikes can potentially be used to locate paleomagma chambers and perhaps even paleo-hotspot centers (Halls 1982).

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Preliminary Results

Dike Dips

In a given area, all dikes of the same trend were found to have similar dips, which are often significantly different from vertical (Figure 1, Table 1). This departure from vertical may be explained in the following ways:

1. intrusion into rock along inclined mechanical anisotropy (foliation or fracturing)
2. a stress regime caused non-vertical fracturing followed by dike injection
3. post-intrusion deformation (i.e. crustal flexure or block tilting) which modified an original primary vertical dip

Explanation 1 can be eliminated because most of the data was collected from dikes which cut massive potassic granites. Also, any host-rock grain present was usually cross-cut by the dike at a random oblique angle. At least some of the data can be explained by known post-intrusion tectonic tilting (Explanation 3). The dip of dike sets E and F (Figure 1) fit the accepted block tilting origin for the southern segment of the Kapuskasing Structural Zone (i.e. uplift around an axis of about N20°E with the detachment zone to the east) (Card *et al.* 1981). The northward dip of dike set A results from sagging of dense basalt-laden Keweenawan crust to the south (Halls and Pesonen, in press; Ayres 1969). The cause of the other systematic dips is still under consideration.

Phenocryst Distribution in Matachewan Dikes

The north- to north-northwest-trending dikes of the 2.6 Ga Matachewan swarm contain phenocrysts of saussuritized plagioclase distributed in a pattern which is very irregular both on the scale of a single dike and of the swarm. Study of the phenocryst distribution in 23 north- to north-northwest-trending dikes along a 30 km stretch of Highway 144 northeast and southwest of Gogama leads to these two important conclusions about the nature and origin of the phenocrysts of this part of the Matachewan swarm:

1. Where present, the phenocrysts always occur in a second intrusive phase which has intruded a phenocryst-free primary dike phase. The multiple intrusive nature is demonstrated by inclusions of the first phase in the second and by examples of a chilled zone of the sec-

TABLE 1 DIKE DIPS IN THE CENTRAL SUPERIOR PROVINCE, NORTHERN ONTARIO

DIKE SET	NUMBER OF DIKES	AVERAGE DIP VALUE	1σ VARIATION OF DIP	SWARM NAME	APPROXIMATE AGE (Ma)	REFERENCE FOR DIP DATA
A		70°-80°N		Pukaskwa	1100	Halls (pers. comm.)
C	3	65°NW		Abitibi or Preissac (?)	1100 or 2150	this study
F		70°-80°SE		Abitibi and/or Preissac	2150	Card *et al.* (1981)
J	3	74.3°S	5.5	Abitibi and/or Preissac	2150	this study
B	9	81.7°SW	5.6	Hearst	2600	Ernst (1981)
D	13	86.9°W	10.2	Hearst and		this study
	10	81.6°W	4.8	Post-Huronian (?)		
E	11	80.8°E	4.5	same as D		Ernst (1981) Card *et al.* (1981)
G	5	89.9°W	5.5	Matachewan	2600	this study
H	6	79.3°W	8.2	Matachewan	2600	this study
K	23	83.4°E	6.2	Matachewan	2600	this study
L	15	83.2°E	6.2	Matachewan (?)	2600	this study
M	6	89.3°E	11.7	Matachewan	2600	this study

ond phase in contact with a coarse interior portion of the first.

2. Two adjacent dikes along this stretch of Highway 144 have a spectacularly porphyritic second phase. In both dikes, this phase has a phenocryst to groundmass ratio greater than 4:6, large single phenocrysts up to 6 cm in size, and huge agglomerations of plagioclase approaching 0.4 m in diameter. This second (phenocryst-containing) phase is generally absent from other dikes to the northeast and southwest and, where present, has a lower phenocryst/groundmass ratio and smaller phenocryst size (less than 3 cm). Furthermore, this second phase progressively decreases in abundance with increasing distance from the two intensely porphyritic dikes.

One must conclude that the phenocrysts are derived locally as either products of fractional crystallization of the dike magma or they are xenocrysts from an anorthositic body through which the dike magma moved. These two models will be tested geochemically. If the phenocrysts result from *in situ* fractional crystallization then the dike groundmass should have a strong negative europium anomaly. If, however, the crystals are actually xenocrysts, and providing that the dike magma has not crystallized elsewhere and lost plagioclase, then no europium anomaly should be present.

Geochemistry of a 550 km Long Abitibi Dike

A single northeast-trending Abitibi dike (Figure 1) about 1100 Ma in age (Fahrig 1972) has been traced on aeromagnetic maps for 550 km from near Foleyet, Ontario, to Chibougamau, Quebec. It essentially cross-cuts the Abitibi Subprovince from the Kapuskasing Structural Zone to the Grenville Front. A total of 50 geochemical samples were collected in traverses across the dike at 6 spaced intervals along its length (funding for the Quebec portion of the field work was supplied by the National Science and Engineering Research Council). The geochemical analyses of these samples will be used to:

1. test and model the degree of chemical fractionation from margin to interior and test the extent of multiple intrusion
2. look for systematic variations in geochemistry and petrology along the dike in order to test the model of subhorizontal magma flow (Halls 1982)

A preliminary hand sample comparison of the coarse interior samples along the length of the dike shows a subtle trend of mafic enrichment to the southwest (colour index is about 40 at the northeastern and about 50 at the southwestern end of the dike). If a simple model of subhorizontal flow applies then the magma was derived from the southwest, perhaps from the Keweenawan rift system of the same age. The geochemical results should provide a conclusive test.

Microcryst Orientation as a Flow Indicator

The flow direction can potentially be determined directly by measurement of the orientation of elongate microcrysts in chilled dike margins. Members of most of the

dike swarms of northern Ontario contain such microcrysts of plagioclase which range in size from 0.1 to 1 cm. Samples have been taken of Matachewan and Sudbury dikes as well as the 550 km Abitibi dike to test for preferred feldspar orientation. Preliminary observations reveal that the crystals in all cases are aligned parallel to the dike walls. The lineation in the plane of the dike, which will give the inclination of flow, is more subtle. Measuring it will require a rigorous method of serial sectioning and fabric analysis (Grunsky 1978).

Development of effective techniques to determine the direction of magma flow in dikes could be very important from the viewpoint of locating magma feeder chambers, especially if the flow inclination is found to vary systematically across and along swarm. Application of flow direction analysis could conceivably be further extended to sills and gabbroic bodies and have direct economic implications. For example, the Nipissing sills are associated with silver and cobalt mineralization but the source of the metals is unknown. Determination of the flow direction could aid in locating the source.

As the preliminary results of this summer's work have shown, the regional characteristics observed in mafic dikes gives promise that swarms may be useful in further unravelling the tectonic and magmatic history of shield areas.

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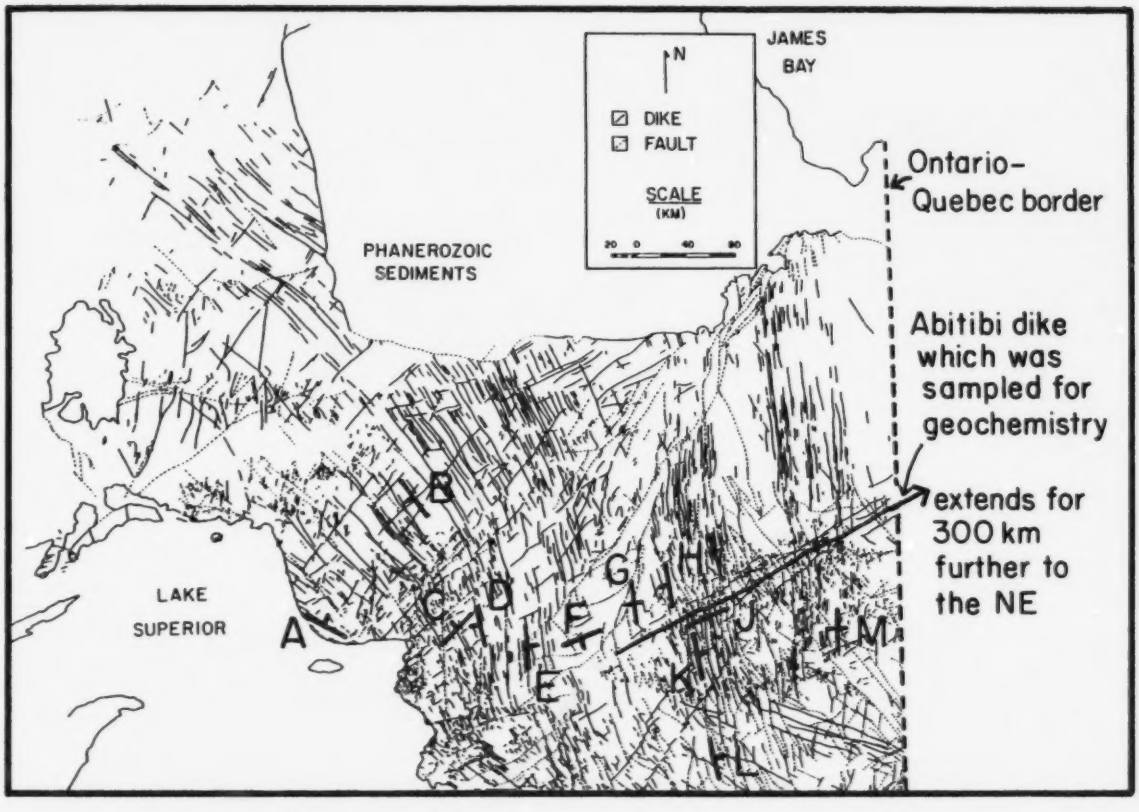

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No. S1 Geology of the Lumby Lake Area (Eastern Half), Districts of Kenora and Rainy River

M.C. Jackson[1]

THIS PROJECT WAS FUNDED EQUALLY BY THE GOVERNMENTS OF CANADA AND ONTARIO UNDER THE NORTHERN ONTARIO RURAL DEVELOPMENT AGREEMENT (NORDA).

Introduction

The first year of a two-year project on the Lumby Lake "greenstone belt" was spent in the eastern half of the area. The 145 km² area is bounded by Latitudes 49°00'N to 49°07'30''N and Longitudes 91°00'W to 91°15'W. The center of the map-area lies approximately 50 km northeast of Atikokan on Highway 11 and 20 km southwest of English River on Highway 17.

Excellent access to the area is provided by numerous logging roads. Active logging is currently underway in the area. The main haulage roads can be reached by driving north on Highway 623 (24 km east of Atikokan on Highway 11) or south from Martin on Highway 17.

Fieldwork was concentrated on the supracrustal rocks of the Lumby Lake "greenstone belt". Mapping was done at a scale of 1:15 840 (4 inches to 1 mile). Granitoid bodies north and south of the belt were not examined in detail. Bedrock exposure in the area is moderate to poor with extensive cover by Quaternary surficial deposits of sand and gravel.

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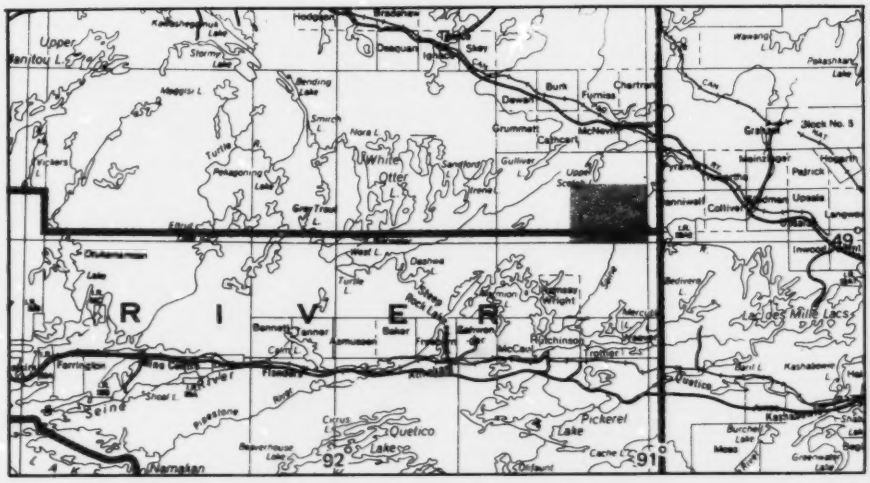
Mineral Exploration

Gold was first discovered in the western part of the Lumby Lake area in the 1890s at Longhike Lake. This discovery led to the only mineral production in the area. In 1900, 15 tons of gold ore, with an average grade of 0.29 ounce per ton, were milled from the Golden Winner Mine (Wilkinson 1982, p.26). In 1937, gold was discovered at Lumby Lake, resulting in considerable prospecting activity until the early 1950s. In the eastern half of the Lumby Lake area, exploration has been concentrated on examination of iron deposits. The occurrence of limonite gossan at Hematite Lake was first reported in 1914. The iron formation was extensively investigated by over 5000 feet of diamond drilling, from 1948 to 1952, by Candela Development Company. Steep Rock Iron Mines Limited also worked in the area in the 1950s and 1960s. Other parts of the area have been staked and prospected for base metals by Noranda Mines Limited (1967), Canadian Nickel



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

Company Limited (1968 to 1972), and Falconbridge Nickel Mines Limited (1970 to 1975) (Schneiders and McConnell 1981). The most recent exploration activity consists of claims staked after the release of the 1980 Ontario Geological Survey Airborne Electromagnetic and Total Intensity Magnetic Survey (Wadge 1980, p.151; Ontario Geological Survey 1980), which shows a multitude of "INPUT" electromagnetic conductors in the area. Currently, large blocks of claims are being worked by Steep Rock Iron Mines Limited and Mining North Exploration Limited; both companies are based in Atikokan, Ontario. Smaller claim groups have been staked in the area by individual prospectors.

General Geology

The Lumby Lake "greenstone belt" occurs as an isolated and irregularly shaped remnant of supracrustal rock in the dominantly granitoid terrain of the Wabigoon Subprovince of the Early Precambrian (Archean) Superior Province.

Previous work (Woolverton 1960) has outlined the major geological units of the Lumby Lake "greenstone belt". This project has added much detail to the previous mapping. The belt consists mainly of mafic to intermediate metavolcanics overlain by a sedimentary unit consist-

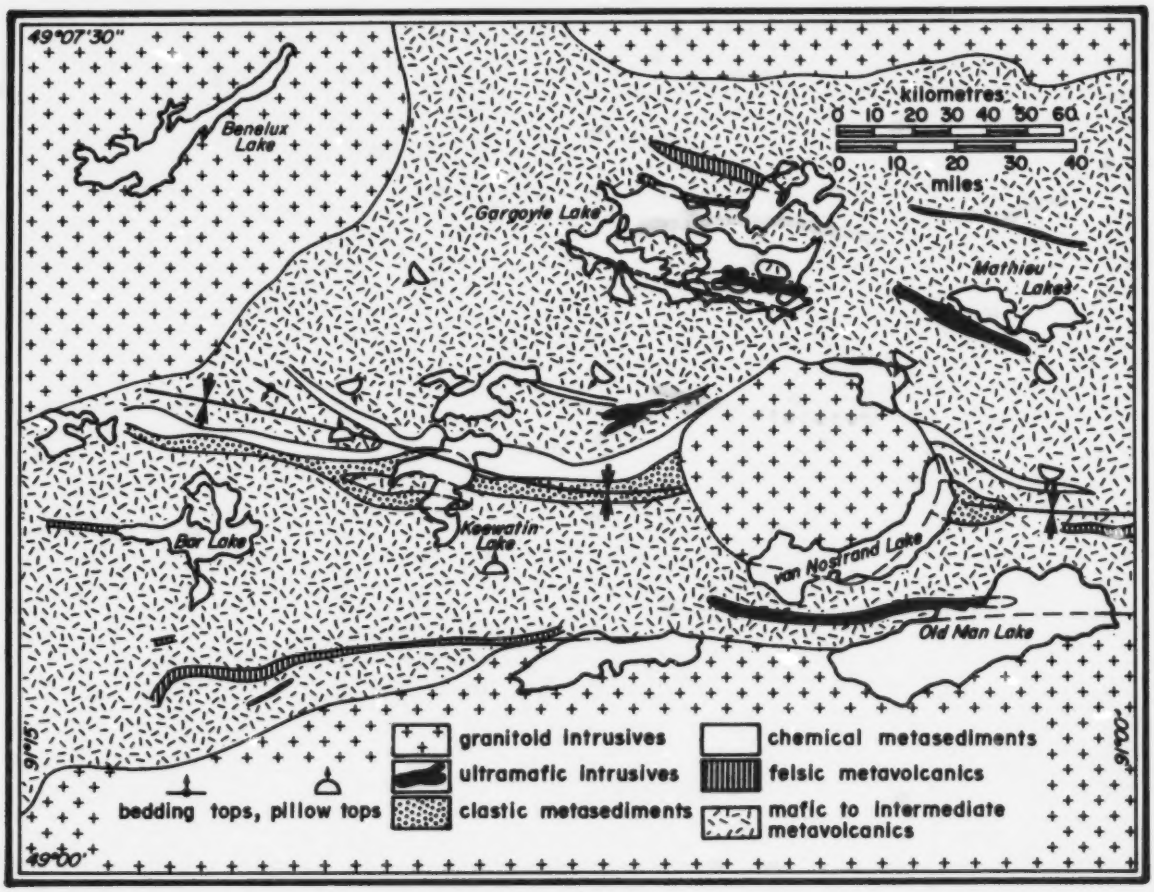


Figure 1—Generalized Geology of the Lumby Lake Area (East Half)

ing of iron formation and clastic metasediments which form the core of an east-trending syncline. A small, circular quartz monzonite porphyry stock cuts the axis of the syncline in the centre of the map-area. This year's work has discovered numerous further units of ironstone associated with graphitic argillite on the north limb of the syncline, and a number of thin felsic metavolcanic units not delineated by previous mapping. Furthermore, units tentatively identified as peridotite were found to be more extensive than previously indicated.

Mafic metavolcanics consist of pillowed to massive flow units with rare pillow breccia. Pillows are generally small, 0.1 to 1.0 m in diameter, and often have a concentric amygdaloidal zone 2 to 3 cm from the pillow rim. Both plagioclase porphyritic and variolitic mafic lithologies also occur throughout the area.

Felsic metavolcanics consist dominantly of thin (10 to 20 m) crystal tuff to lapilli-tuff units composed almost exclusively of quartz and plagioclase crystals, and generally lacking internal structures. Some units of dense aphanitic rhyolite with 2 to 5 percent quartz phenocrysts may represent felsic flows or welded tuffs.

Chemical metasediments consist of chert, ferruginous chert, ironstone, and marble. Ferruginous dolomite (ankerite) also occurs but may be of secondary origin. Ironstone units are generally less than 100 m thick, are irregular in outcrop pattern, structurally disrupted, and are highly varied in lithology. There are changes along and across strike from oxide (magnetite) and carbonate (siderite) facies banded ironstones to sulphide (pyrite) facies. Silicate facies may also occur. Graphitic argillite is commonly associated with ironstones and is especially common, associated with or as a matrix to, concretionary sulphide mineralization (pyrite).

Clastic metasediments are dominantly fine-grained, massive argillites. Thinly bedded lithic wackes also occur, and are locally abundant especially in the vicinity of Pinecone Lake.

Sedimentary structures are rarely observed but graded bedding and crossbedding were observed in two locations near Pinecone Lake.

Probable ultramafic rocks occur as four separate, broadly conformable bodies around the Van Nostrand Stock (Figure 1). Parts of two of these bodies were previously recognized by Woolverton (1960). These rocks are dark grey to dark green on a fresh surface and light grey to white on a weathered surface. They are usually strongly magnetic, and in outcrops on the north shore of Old Man Lake abundant veinlets of magnetite occur. Although no primary extrusive structures such as pillows or flow breccias were observed in these rocks, the possibility that at least some of them represent extrusive komatiites must be entertained. However, at least one of the bodies (west of Van Nostrand Stock) exhibits a cross-cutting outcrop pattern.

At least two, and possibly three, generations of granitoid rocks border the Lumby Lake "greenstone belt". The oldest granitoid rocks are probably the Marmion Lake gneisses which border the south side of the belt. These rocks (designated as Laurentian granite by Woolverton 1960), consist of tonalitic gneisses, massive to foliated, cut by dioritic intrusions. A contact zone, consisting of metavolcanics, intrusive quartz porphyry, diorite, and gabbro, between the Marmion Lake gneiss and the "greenstone belt" gives the impression of a diffuse contact although some workers have interpreted a fault contact here (Pye and Fenwick 1965).

Granitoid bodies north of the "greenstone belt" consist of the Chill Lake granodiorite, a massive medium- to coarse-grained mafic-poor body outcropping on the northeastern edge of the "greenstone belt", and the Norway Lake pluton, a pink-coloured porphyritic granite with syenitic phases. The latter body may be post-tectonic in age (Schwerdtner *et al.* 1979, p.1973); this interpretation is supported by its cross-cutting to perpendicular aspect to the volcanic stratigraphy of the "greenstone belt".

The Van Nostrand Stock is a roughly circular quartz monzonite porphyry intrusion 4 km in diameter, which cuts the center of the "greenstone belt". It is a largely homogeneous body, but in places has a monzodioritic(?) border phase. A distinct, but narrow (about 500 m) contact metamorphic aureole containing migmatitic rocks surrounds the stock. The stock is similar in composition, texture, and possibly in age, to the Norway Lake pluton.

Structure

The structure of the Lumby Lake "greenstone belt" is undoubtedly complex, but the lack of structural indicators and the discontinuous and sporadic nature of outcrops make interpretation difficult. Facing directions determined in mafic metavolcanics and metasediments by means of pillows and graded bedding, respectively, indicate that the dominant structure is an east-trending syncline with an axis running through the Van Nostrand Stock. This syncline is markedly asymmetrical both in its geologic and geophysical expression, with distinctly greater aeromagnetic and electromagnetic response north of the central axis. A number of inconsistent facing determinations indicated that there are minor fold axes on both limbs of the main structure. A few north-trending faults are suspected on the basis of discontinuities in the aeromagnetic contours (Ontario Geological Survey 1980) but these could not be proven geologically. A slight disturbance of stratigraphic contacts in the vicinity of the Van Nostrand Stock suggests that it may have been involved in deformation but the stock itself is massive and structureless.

Economic Geology

There are no known occurrences of economic mineralization in the eastern half of the Lumby Lake area. However, Woolverton (1960) reports a single gold assay of 0.09 ounce per ton from a prospect pit 400 m south of the west end of Brushport Lake (about 600 m east of the eastern

boundary of the map-area) in the northeastern part of the area, and "visible gold is said to occur at several places in the vicinity of Pyramid Lake" (Woolverton 1960, p.42). Numerous gold occurrences are located in the western half of the Lumby Lake area, including one past producer and prospects (Sawdo claims) with a reported assay of over 1.0 ounce gold per ton (Wilkinson 1982, p.47-50). Thus excellent potential for gold mineralization exists in the eastern half of the Lumby Lake area and further prospecting is warranted. Initial results of assays on samples collected during the 1982 field season indicate an anomalous gold concentration in graphitic argillite associated with ironstones in the area. A value of 180 parts per billion gold (0.005 ounce per ton) was obtained in graphitic argillite containing pyrite concretions from an old prospect pit at Cryderman Lake shown on Woolverton's (1960) map. Ankeritic carbonate zones with quartz veins were discovered in the area near Brushport Creek and, although no assays are yet available of this material, high gold values are reported in identical lithologies in the western half of the Lumby Lake area (1.99 ounces gold per ton; Woolverton 1960, p.42).

Although gold is considered the best exploration target in the area, potential for base-metal mineral deposits also exists. Massive sulphide bodies occur within the central ironstone unit between Hematite and Keewatin Lakes and at Pinecone Lake. The latter body runs 395 parts per million copper and contains a trace of visible chalcopyrite in massive pyrrhotite ± pyrite. These bodies are generally small (less than 10 m^3) where observed in outcrop, but a possibly continuous unit 1 km long and averaging 17 m in thickness was explored by drilling between Keewatin and Hematite Lakes (Woolverton 1960, p.49). This body occurs at the contact of the ironstone-chert unit and the overlying clastic metasediments and, like all other massive sulphide bodies observed, consists exclusively of iron sulphide mineralization (pyrite ± pyrrhotite). Sulphide-rich ironstone also occurs southeast of Pipestem Lake and in the southern part of Gargoyle Lake. One sample of ironstone from the southwestern shore of Gargoyle Lake contains 775 parts per million copper. The discovery of numerous thin felsic metavolcanic units in the area is encouraging in terms of the volcanogenic model of Kuroko-type copper-lead-zinc massive sulphide deposits, although no mineralization has yet been found associated with these bodies. Potential also exists for the occurrence of copper-nickel, and/or chromium, and/or platinum group metals associated with the ultramafic bodies. Veins of chrysotile asbestos, 1 to 2 cm wide, occur in some of the ultramafic units, especially at Gargoyle Lake and south of Mathieu Lake.

The potential for iron deposits in the area has been explored in the past. The exposed ironstone units are generally narrow and inhomogeneous and are probably not economical at the present time. However, this year's mapping has revealed numerous additional ironstone units not previously recognized (Woolverton 1960), and each unit should be examined separately and evaluated on its own merits. Furthermore, even if the ironstone units are not economic deposits of iron, they are potential hosts of gold and/or base-metal deposits.

The variety of granitoid bodies and the well developed contact metamorphic aureoles around some of the intrusive bodies indicate potential for copper-molybdenum and/or skarn mineralization. Gold occurrences are known in the Marmion Lake gneisses outside the map-area (Wilkinson 1982).

Eolian sand and glacial gravel deposits are abundant in the area.

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No. S2 Mishewawa Lake Area, District of Algoma

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Introduction

The map-area, composed of the townships of Rabazo and Naveau, lies approximately 7 km south of the Town of Wawa. It is bounded by Latitudes 47°50′N and 47°56′N, and Longitudes 84°36′45″W and 84°52′10″W.

The Trans-Canada Highway (Highway 17) passes along the western side, and the Michipicoten River runs through the northern part of the area. A good all-weather road runs along the northern side of the Michipicoten River to McPhail Falls, from where 4-wheel drive vehicles are needed to travel into southern Naveau Township. Mishewawa and Kashog Lakes are accessible by float-equipped aircraft. The southern half of Rabazo Township lies within the boundaries of Lake Superior Provincial Park and is accessible only by canoe and foot.

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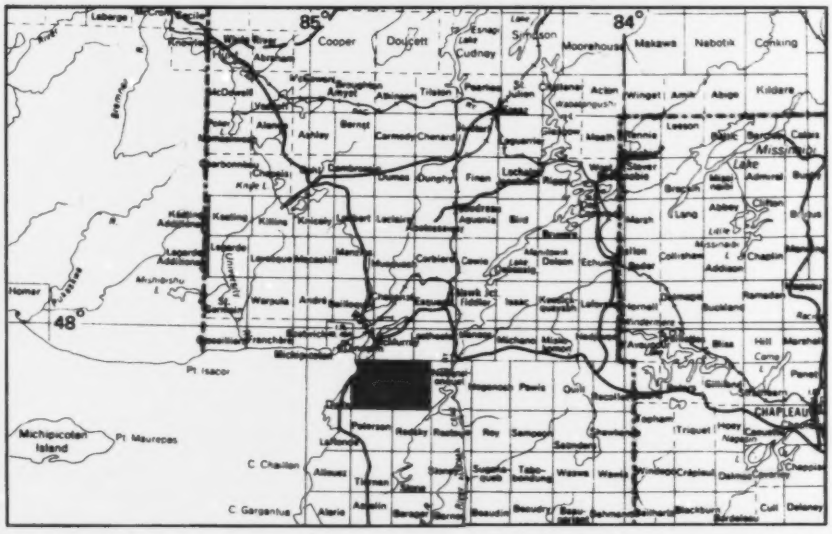
Mineral Exploration

Exploration for gold, base-metals, and iron has been carried out within the area since the Wawa camp opened in 1897. However, the records of earlier work are poor, and this account is based on the information available in the Regional Geologist's Files, Ontario Ministry of Natural Resources, Sault Ste. Marie; the Mining Recorder, Algoma Central Railway, Sault Ste. Marie; and various Ontario Geological Survey reports (Coleman 1906; Gledhill 1927; Frohberg 1937; Rupert 1979).

Much of the prospecting work, particularly that done in the northern part of Rabazo and the northwestern corner of Naveau Townships, has been centred on the search for gold. Three deposits reached production: the Norwalk, Centennial, and Ranson Mines.

Mining operations at the Norwalk Mine started in 1901 when Manxman Gold Mining Company sank an inclined shaft to a depth of 25 m along a gold-bearing quartz vein in sheared granodiorite. Mining continued until early 1903. During 1909 and 1910, the Norwalk Mining Company deepened the main shaft to 64 m. The 'Fred C'



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

shaft was also sunk at this time to a depth of 39 m into a pyrrhotite-chalcopyrite-quartz vein in mafic metavolcanics. Operations ceased in 1910. In total about 60 ounces of gold were produced (Ferguson *et al.* 1971). More recent appraisals of this and adjacent properties have been conducted by Candore Explorations Limited (1963) and Canabec Explorations Limited (1978 to 1982).

The Centennial Mine was originally developed by the Kitchi-Gammi Mining Company Limited during 1904 and 1905. Four shafts were sunk along a gold-bearing quartz vein, hosted in massive granodiorite. Underground exploration was undertaken in 1935 by L.B. United Mines Limited. Between 1937 and 1939 a new inclined shaft, with levels at 38 m and 76 m, was sunk by Agawa Gold Mines Limited and a new mill was constructed. The mine was reopened in 1939 and produced 610 ounces of gold and 36 ounces of silver (Ferguson *et al.* 1971) before ceasing production in 1940. Activity since has been restricted to surface exploration by prospectors.

No records remain of the development and production of the Ranson Mine. The main gold-bearing quartz vein follows a major fracture in a gabbro host, but several other mineralized zones occur on the property, with quartz veins in mafic metavolcanics and feldspar porphyry. The property is presently undergoing investigation and development by J. Longhurst.

Various localities in Rabazo and Naveau Townships have been investigated in recent years by the Algoma Steel Company Limited for iron, and a group of properties in the Moon Lake area are currently under study by Noranda Exploration Company Limited for gold. An airborne electromagnetic and total intensity magnetic survey covering much of the area was released by the Ontario Geological Survey (1980).

General Geology

The Mishewawa Lake area forms the southernmost extension of the Wawa "Greenstone Belt". Mapping was restricted mainly to areas underlain by metavolcanics (Figure 1).

The mafic metavolcanic succession shows a general progression from massive flows at the base, upwards into pillowed lavas (some variolitic), pillowed lavas and tuffs, and finally tuffs and chlorite schists.

Felsic metavolcanics consisting of intermediate to felsic tuffs and crystal tuffs occur sporadically throughout the upper part of the mafic metavolcanic sequence. Thicker units overlying the mafic metavolcanics occur in the Dycie Lake-Scott Falls area; northwest of Kashog Lake and east of Moon Lake.

Chemical metasediments consisting of chert and banded iron formation, usually oxide facies, occur in several localities. Unlike the iron formation farther north in the Wawa Belt (Goodwin 1962), these occurrences are restricted in thickness and strike length. They also occur interlayered with both mafic and felsic metavolcanics.

Gabbroic and diabasic intrusions of probable Early Precambrian (Archean) age are common in the area, many appear to be sub-concordant sills within the mafic volcanic pile. Larger bodies are found northwest and west of Treeby Lake. Three felsic bodies also intrude into

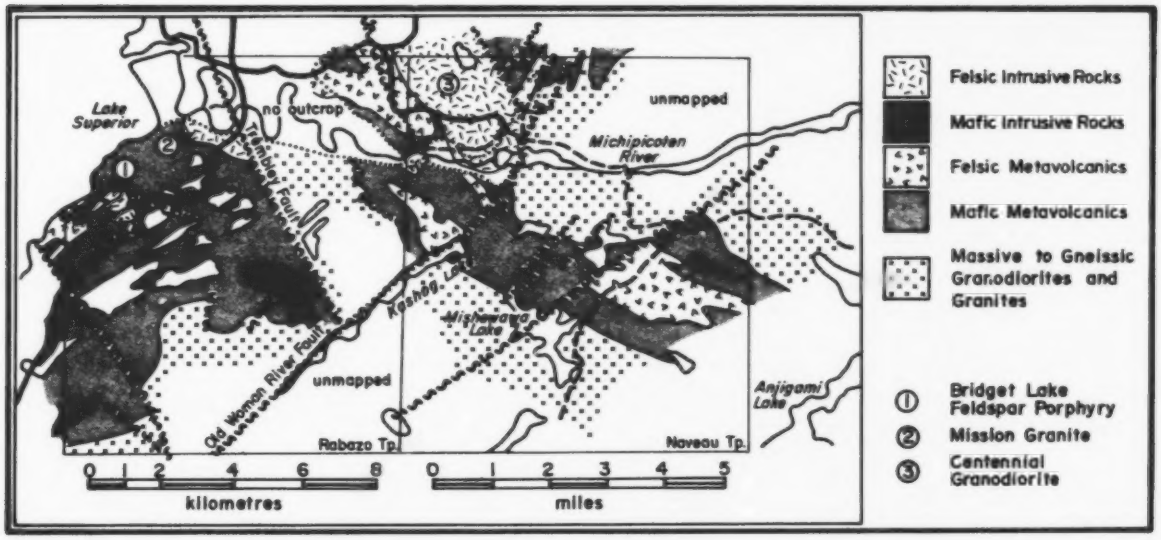


Figure 1—Geology of the Mishewawa Lake area.

the metavolcanics, namely the Bridget Lake Feldspar Porphyry, the Mission Granite, and the Centennial Granodiorite. Minor felsic dikes are also present.

Diabase and lamprophyre dikes of probable Keweenawan age cross-cut the area.

The metavolcanic sequence is probably correlative with the "Lower Cycle" metavolcanics of McMurray, Lastheels, and Esquega Townships (Sage 1981), although the felsic metavolcanics in the Dycie Lake-Scott Falls area may be correlative with the "Upper Cycle" (Sage 1981).

Structural Geology

The metavolcanic rocks within the "greenstone belt" show evidence of at least two phases of deformation. The first produced a foliation that is commonly subparallel to bedding, where bedding is discernible, but can be seen to be axial planar to small folds in banded iron formation and intrafolial folds within tuffs and schists. This first foliation is dominant within most of the mapped area and commonly trends 100° to 125°, usually with a steep dip. Shears in gabbro and the Centennial Granodiorite also have similar trends

The first foliation was deformed by a second event which produced crenulation cleavages and kink bands. The trend of this second foliation varies from northwesterly to northeasterly. The general swing to northeast-striking foliations within the western part of Rabazo Township results from reorientation of the first foliation in this area, although a few outcrops retain the east-northeasterly directions.

Within the central part of Naveau Township, dips of the metavolcanics, though always steep, vary from southwesterly in the northern part of the "greenstone belt" to northeasterly in the southern part. This configuration, coupled with the presence of felsic metavolcanics in the centre, suggests a synformal structure to the belt. The sequence of metavolcanics north of Blackington Lake is inverted, with steep dips to the south-southwest but facing directions to the north-northeast. Within the rest of Rabazo Township, facing direction is less certain.

Several major faults cut the area. Within Rabazo Township they generally trend southeasterly, whereas in Naveau Township they trend northeasterly. In nearly all cases, apparent offsets are sinistral, most spectacularly so along the Trembley Fault with offsets of about 5 km. The southeast-trending faults appear to terminate against the northeast-trending Old Woman River-Firesands River Fault, which suggests that they may be the older.

Economic Geology

Gold

Gold mineralization within the area is confined to quartz veins which either follow regional foliation or infill shears and faults. Host rocks vary considerably from mafic to felsic metavolcanics, as well as intrusions. The Norwalk and Centennial Mines are both within the Centennial Granodiorite, and the Ranson Mine has sheared gabbro as its host rock. Throughout most of the area disseminated sulphide mineralization is common in mafic metavolcanics and mafic intrusions. Carbonate alteration of rocks is limited to the Dycie Lake-Scott Falls area, though carbonate veins are common in other areas. Chloritoid alteration such as that found further north in the Wawa Belt (Sage 1981) is absent in this area.

Other Metals

Galena, associated with pyrite and chalcopyrite, occurs in quartz veins within the Mission Granite and within mafic metavolcanics in the Dodds Lake-Nezwa Lake area. Pyrite-rich and magnetite-rich chlorite schists are also found in the Crozier Lake area.

Iron formations in Rabazo Township appear to be thin and discontinuous and are likely of little economic importance as far as their iron potential, although their gold potential is still uncertain. Strong aeromagnetic anomalies in Naveau Township, north of Fir Lake, suggest the possibility that more extensive iron formation could be present in this area. Past prospecting activity (Resident Geologist's Files, Ontario Ministry of Natural Resources, Sault Ste. Marie; Mine Recorder, Algoma Central Railway, Sault Ste. Marie) suggests that the iron formation could be of the sulphide-facies variety.

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No. S3 Black River-Matheson Area, District of Cochrane

N.F. Trowell[1]

THIS PROJECT WAS FUNDED EQUALLY BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS AND THE ONTARIO MINISTRY OF NATURAL RESOURCES.

Introduction

Field work done in 1982 represents the first part of a multi-year program to carry out detailed, synoptic, and stratigraphic mapping along the Destor-Porcupine Fault from east of Timmins to the Quebec border.

The map-area covered this past year is bounded by Latitudes 48°30'00'' N and 48°37'30'' N and Longitudes 80°20'00'' W and 80°49'00'' W, and covers an area of approximately 400 km². It comprises the townships of Stock, Taylor, Carr, and parts of Bond, Currie, Bowman, and Beatty. The Town of Matheson is situated in the east-central part of the area and Timmins is approximately 60 km to the west. Highways 11 and 101 pass through the central part of the map-area. Concession roads provide access to the rest of the map-area.

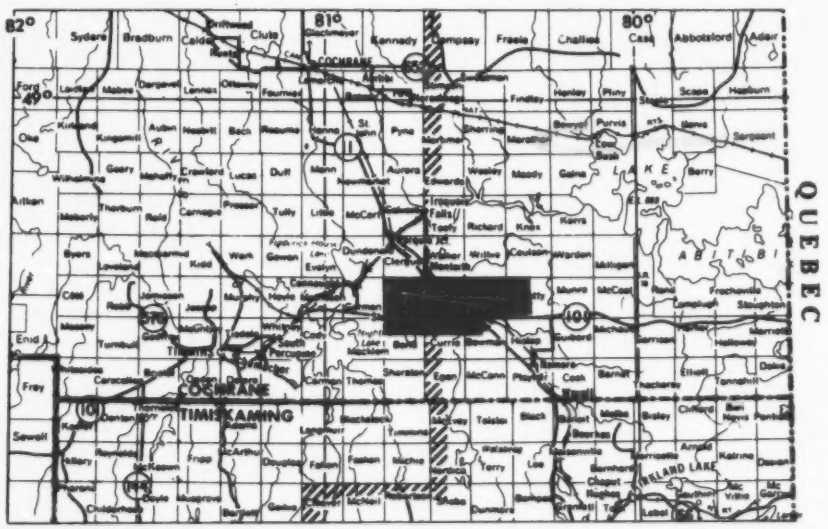
[1]Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

Mineral Exploration

Unless otherwise stated, the information reported here on exploration activity was obtained from the Resident Geologist's Files, Ontario Ministry of Natural Resources, Timmins and Kirkland Lake, or Assessment Files Research Office, Ontario Geological Survey, Toronto.

In any consideration of mineral exploration in the map-area, it should be pointed out that with the exception of the northern half of Beatty Township, the remainder of the area has from <5 to <1 percent outcrop. Overburden, primarily varved clay, varies in depth from a few metres to in excess of 60 m. Exploration, primarily for gold but also for base metals, that began at the turn of the century, usually involved initial geophysical surveys: magnetometer and often electromagnetic, with follow-up diamond drilling of anomalies. This procedure is reflected in the compilation of assessment work and mineral exploration given in Table 1.

The majority of exploration has been directed towards delineation of, and selection of anomalies in the vicinity of the Destor-Porcupine and Pipestone Faults. Dia-



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles.

TABLE 1 | **TABULATION OF ASSESSMENT WORK AND MINERAL EXPLORATION, BLACK RIVER-MATHESON AREA**

COMPANY	NUMBER OF PROPERTIES*	EXPLORATION WORK DONE	YEAR DONE	COMMENT/REFERENCE
BOND TOWNSHIP				
Hollinger Mines Ltd.		2	1976	
Ingamar Exploration Ltd.		7	1976	
STOCK TOWNSHIP				
Asarco Exploration Company of Canada Ltd.	2	1,2	1980	
		1,2	1980	
Bird, S.J.		5	1939	
Clavos Porcupine Mines Ltd.		5	1973	work done by Noranda Exploration Company Ltd.
Clodan Gold Mines Ltd.		1	1946	
Dalhousie Oil Company Ltd.		5	1980	
Evoy, Norman		5	1961	
		1	1963	
Hollinger Argus Ltd.		5	1980, 1982	
Hollinger Consolidated Gold Mines Ltd.		5	1964	
Hollinger Mines Ltd.		1	1979	
Mining Corporation of Canada (1964) Ltd.		1,2	1974	name changed 1977 to Mining Corporation of Canada Ltd.; work done by Noranda Exploration Company Ltd.
	3	1	1974	
		1	1974	
Mulliette-Bell		1,2	1974	
Newman, Roy C.		5	1964	
Quebec Sturgeon River Mines Ltd.	2	5	1973	
		5	1974	
Stairs Exploration and Mining Company Ltd.	2	1,2	1964	name changed, 1980, to Regal Goldfields Ltd.
		1,2	1964	
Surveymin Ltd.	2	1,2	1980	now Nahanni Mines Ltd.
		1,2	1980	
Windfall Oils and Mines Ltd.		1,2	1973	
CURRIE TOWNSHIP				
Anderson Prospect				Leahy 1965
Asarco Exploration Company of Canada Ltd.		2	1975	work done by Tillex Syndicate
Duncan R. Derry Ltd.		2	1975	work done by Tillex Syndicate
Falconbridge Nickel Mines Ltd.		1,2	1976	
TAYLOR TOWNSHIP				
Hollinger Argus Ltd.		5	1980	
Hollinger Consolidated Gold Mines Ltd.	2	5	?	no location or drill logs in file
		5	1962, 1963, 1964	
Quebec Sturgeon River Mines Ltd.				Ontario Securities Commission Report
Taylor Gold Mines Ltd.	3	3,4	1965	
		3,4	1965	
		3,4	1965	
N.A. Timmins Exploration (Ontario) Ltd.		5,6	1945, 1946	drillhole locations only, no logs
Turney, W.H.		1	?	
		5	1964, 1965, 1968, 1972	
Windfall Oils and Mines Ltd.		1,2	1973	
BOWMAN TOWNSHIP				
Bird, S.J.		5	?	
Duncan R. Derry Ltd.	3	1,2	1975	work done by Tillex Syndicate
		6	1975	work done by Tillex Syndicate
		1,2	1975	work done by Tillex Syndicate
Young Davidson Mines Ltd.		1	1975	
		2	1975, 1976	

TABLE 1 (continued)

COMPANY	NUMBER OF PROPERTIES*	EXPLORATION WORK DONE	YEAR DONE	COMMENT/REFERENCE
CARR TOWNSHIP				
Carr-Hislop Gold Syndicate		8	1939	
Dominion Gulf Company		1	1954	
Hollinger Consolidated Gold Mines Ltd.	2	5	1939	
		5	1964	
Jeffris Prospect		5	1964	
		6	?	
Wilcarr Mines Ltd.		1,5,6	1946	
BEATTY TOWNSHIP				
Aljo Mines Ltd.**				Satterly and Armstrong (1949)
Amalgamated Gold Fields Corporation Ltd.				Satterly and Armstrong (1949)
Amax of Canada Ltd.		4	1978	
		6	1981	
Argyll Gold Mines Ltd.				Satterly and Armstrong (1949)
Bird, S.J.		5	1947	
Headwater Gold Mines Ltd.			1963	prospectus
Hollinger Consolidated Gold Mines Ltd.	3	5	1962	
		5,6	1966	
		1,2,5	1939	
Lucky Ben Gold Mines Ltd.				Satterly and Armstrong (1949)
Lynch, H.R.		5	1947, 1964	
Lynco Resources Incorporated		5	1973	
		1,2	1980	
Maude Lake Gold		6,8	1982	
Noranda Exploration Company Ltd.	2	5,1,2	1972, 1973	
		5	1980	
Ornum Copper Mines Ltd.		5	1956, 1957	
Stewart-Abate Gold Mines Ltd.		5,6	1958	

* Only one property in township shown by space
** Past Producer

LEGEND FOR EXPLORATION WORK
1 Ground magnetometer survey
2 Ground electromagnetic survey
3 Airborne magnetometer survey
4 Airborne electromagnetic survey
5 Diamond-drilling
6 Geological Survey
7 Airborne Gamma Ray Spectrometer Survey
8 Trenching, assaying

mond drilling along these structures indicates the presence of a sequence of ultramafic and mafic rocks that are locally cut by gold-bearing quartz-carbonate veins and stringers. These rocks were likely originally volcanic flows, of komatiitic affinity, that were subsequently altered to various carbonate, chlorite, talc, and serpentine-bearing schists. Sulphide minerals, specifically pyrite and arsenopyrite but also including galena, sphalerite, and chalcopyrite, are reported to accompany the gold. Metasediments, including chert, graphitic horizons, and conglomerates and wackes of ultramafic composition situated along these faults are also reported to contain gold mineralization.

The only 2 past producers in the area, Aljo Mines Limited (42 ounces of gold from 2333 tons of ore milled, Satterly and Armstrong 1949), and Argyll Gold Mines Limited (30.23 ounces of gold from 25 tons of ore milled, Satterly and Armstrong 1949) comprise fracture-filled gold-bearing quartz veins that cut magnesian tholeiitic flows in northwestern Beatty Township. There are mafic to ultramafic intrusions in the vicinity of both deposits. Maude Lake Gold is presently developing the former Argyll Gold Mines Limited property (Bob Bennett, Maude Lake Gold, personal communication, 1982).

General Geology

Beginning with Hopkins (1915), several individuals have described the geology of various parts of the map-area (Knight *et al.* 1919; Laird 1931; Moore 1937; Satterly and Armstrong 1949; Satterly 1960a, 1960b; Prest 1952; Leahy 1961, 1965).

All consolidated rocks with the exception of Keweenawan olivine diabase dikes are of Early Precambrian (Archean) age. They consist of a metavolcanic-metasedimentary assemblage intruded by small mafic to ultramafic plutons and dikes, and granitoid dikes.

The metasediments occupy an east-trending belt bordered to the north and south by, respectively, the Pipestone and Destor-Porcupine Faults. They consist of sandstone, variable from arenite to feldspathic wacke, siltstone, and minor mudstone. They were likely deposited by turbidity currents. Metasediments of ultramafic composition, chert, and graphitic horizons are reported from diamond-drill holes (Assessment Files Research Office, Ontario Geological Survey, Toronto) along the Pipestone and Destor-Porcupine Faults. Crossbedded conglomerates and sandstones reported from diamond-drill holes in the southwestern part of the area (Assessment Files Research Office, Ontario Geological Survey, Toronto) were possibly deposited in a fluviatile or alluvial fan environment.

The metavolcanics to the south of the metasediments consist of intercalated iron-rich and magnesian tholeiitic flows with the iron-rich tholeiites increasing in abundance to the south. The metavolcanics to the north consist dominantly of magnesian tholeiitic flows (it is possible that some of these flows could be calc-alkalic rather than magnesian tholeiitic in composition) with minor iron-rich tholeiitic flows in southernmost exposures south of the magnesian tholeiitic flows in Beatty Township.

The iron-rich tholeiitic flows are variably massive, pillowed, amygdaloidal, and porphyritic. They are grey-green to green and commonly magnetic. Autoclastic flow-top breccia is uncommonly present, varioles are locally present, and minor fragmentals of tuff-breccia size are present in Currie and Bowman Townships.

The magnesian flows are variably massive, pillowed, and amygdaloidal. They are commonly variolitic but uncommonly porphyritic. Pillow breccia and hyaloclastite are common. Locally varioles have coalesced to form discontinuous pods of light grey rhyolitic-looking material.

Spinifex-textured flows, basaltic komatiite in composition, are exposed on the west shore of Painkiller Lake in Beatty Township, but pinch out a few 10s of metres in from the shoreline.

Volcanic facies were delineated in the magnesian tholeiitic flow sequence in northern Beatty Township where exposure is most abundant. In southernmost exposures, thick flows consist of a medium-grained base that grades upwards into a generally non-amygdaloidal pillowed flow top. Pillow breccia or hyaloclastite are uncommonly present. In the central area of outcrop, this facies is succeeded upwards by a facies consisting of an alternating sequence of less than 10 m thick massive flows, irregular semi-continuous lenses of sideromelane to slightly microlitic hyaloclastite with occasional isolated pillows, and pillowed flows often amygdaloidal, variolitic, and with substantial development of interpillow hyaloclastite. Northward, the amount of pillowed flows, microlitic hyaloclastites, and broken pillow breccia increase in abundance. In northernmost exposures, a predominantly pillowed sequence, amygdaloidal, locally variolitic, with minor interpillow hyaloclastite is present.

A mafic to ultramafic intrusion consisting predominantly of pyroxenite with minor gabbro and peridotite intrudes the metavolcanics north of Painkiller Lake. A sheared peridotite dike intrudes the pillowed flows situated just south of the shaft of the former Argyll Gold Mines Limited Property. This dike may occupy the eastward extension of the Pipestone Fault. A serpentinized gabbro body is located within the northwestern corner of Stock Township.

A number of feldspar (plagioclase) porphyries cut the metasediments, metavolcanics, and ultramafic to mafic intrusions. They range in composition from leucotrondhjemite to quartz leucogabbro. They can rarely be traced for more than a few 10s of metres before they either pinch or are faulted out. They are locally mineralized containing pyrite and uncommonly chalcopyrite. Some of these dikes may be apophyses off larger, covered, granitoid bodies.

North-northeast- to north-northwest-trending Matachewan diabase dikes cut all lithologies of the supracrustal sequence. Compositionally, they are quartz diabase; texturally they vary from equigranular to feldspar (glomero)porphyritic. They vary in width from <15 cm to upwards of 100 m. They are commonly, but not always, magnetic. Two northeasterly to slightly east-northeasterly trending Keweenawan diabase dikes cut both the supracrustal sequence and the Matachewan diabase dikes. Compositionally they are olivine diabase and are coarse-grained equigranular to slightly (plagioclase, pyroxene) porphyritic.

Metamorphic rank varies from prehnite-pumpellyite facies in Beatty Township to lower greenschist facies rank to the west and south. Actinolite-epidote-bearing assemblages overprint the prehnite-pumpellyite-bearing assemblages in the contact aureoles of assumed buried granitoid bodies and along shear zones. Intrusion of diabase dikes has hornfelsed a few metres of the host rocks.

Local areas of metavolcanics have been effectively silicified by the leaching out of mafic minerals. On the property of Maude Lake Gold (formerly Argyll Gold Mines Limited) a zone of pillowed flows and pillow breccia have a yellowish to creamy hue due to leaching out of the mafic minerals and the development of sericite and of iron-rich brown carbonate.

Carbonatization and the development of talc, chlorite, serpentine, and locally sericite is a prevalent altera-

tion of ultramafic rocks situated along the Destor-Porcupine Fault (Assessment Files Research Office, Ontario Geological Survey, Toronto).

Structural Geology

The supracrustal sequence has not been penetratively deformed. Locally, a schistosity or shear zones have developed due to fault movement. The two major faults in the area are the Destor-Porcupine Fault and the Pipestone Fault. The Destor-Porcupine Fault is both a lithological and structural discontinuity as it separates metasediments to the north from metavolcanics to the south, and is itself localized along a zone of sheared ultramafic and associated mafic rocks. The Pipestone Fault in the western part of the area defines the contact between metasediments to the south and metavolcanics to the north whereas to the east in eastern Carr and Beatty Townships, it separates two metavolcanic assemblages. Other faults developed parallel to stratigraphy have been offset by later northeast-trending faults. Diabase dikes (Matachewan) were in many cases emplaced along north-northwesterly to north-northeasterly trending faults. Late northwest- to north-northwest-trending faults appear to offset all earlier structures.

Opposing facing directions indicate that the supracrustal sequence has been folded, but due to the lack of outcrop, with the exception of Beatty Township, the accurate placement of axial plane traces of folds is not possible.

Economic Geology

Both the ultramafic and associated mafic rocks, and the metasediments along the Destor-Porcupine and Pipestone Faults represent viable exploration targets specifically for gold mineralization. Paucity of outcrop and impermeable clay cover preclude geological and some geophysical, for example Induced Polarization, exploration techniques. Overburden drilling with chemical and mineralogical analysis of basal till could be an effective prospecting method. As well, vertical-gradient magnetometer surveys combined with a knowledge of drift thickness might be useful in defining and thus screening out the effects of overburden cover and thus allow for more accurate delineation of structures and lithological distribution.

In areas of extensive outcrop, such as northwestern Beatty Township, attention should be directed towards the distribution of volcanic facies and the paleotopography of the flows and fragmental units. Hyaloclastite, pillow breccia, and interpillow hyaloclastite invariably contain 1 to uncommonly 3 percent sulphide mineralization consisting of pyrrhotite, pyrite, and locally chalcopyrite. Due to their greater initial porosity, these units were much more permeable than the massive and pillowed flows, and any mineralized solutions would have been focused through them. Places where there could be a possibility of finding accumulations of base and perhaps precious metals would be where hyaloclastite units abut against massive flows such that any mineralizing solutions would tend to pond against the massive flows and, dependent upon chemical conditions, could precipitate out elements of economic interest. While no carbonaceous material was seen in these fragmental units, the presence of such would be a favourable factor, in that biological activity often has a control on deposition of base-metal sulphides.

Since the only two past producers in the map-area, Aljo Mines Limited and Argyll Gold Mines Limited (Satterly and Armstrong 1949), are situated in fracture-controlled gold-bearing quartz veins, attention should be directed towards accurate delineation of the fracture patterns in the area to, if possible, predict the location of those areas where quartz stockworks could have developed.

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No. S4 Hart, Ermatinger, and Totten Townships, District of Sudbury

A.G. Choudhry[1]

THIS PROJECT WAS FUNDED BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS THROUGH THE NORTHERN ONTARIO GEOLOGICAL SURVEY (NOGS) PROGRAM.

Introduction

The map-area covers approximately 280 km² and is bounded by Latitudes 46°27'13"N and 46°42'57"N and Longitudes 81°33'52"W and 81°41'34"W. It includes, from north to south, Hart, Ermatinger, and Totten Townships. The Town of Levack is situated about 15 km towards the east while Cartier is located near the northeastern corner of the map-area. Access into the northern and central parts of the area is provided by gravel roads that extend off Highway 144 at Windy Lake Provincial Park and Cartier. Access to the southern parts of Totten Township is provided by canoe via John Creek, or by helicopter.

Card and Innes (1976, 1981) mapped part of northern Hart Township.

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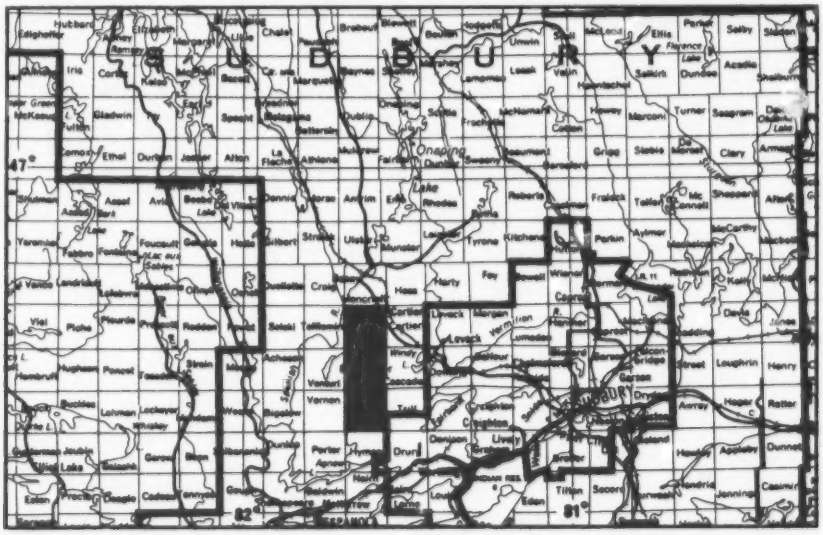
Mineral Exploration

Exploration in the map-area dates back to the early 1950s when Consolidated Mogul Mines Limited (Mogul Mining Corporation Limited in 1958) did some trenching and diamond drilled 12 holes totalling 696 m in north-central Hart Township. Minor amounts of pyrrhotite, sphalerite, galena, pyrite, chalcopyrite, magnetite, cobaltite, and smaltite were encountered in brecciated, contact metamorphosed Huronian metasediments near a contact with Nipissing Diabase. Later in 1965, Salem Exploration Limited conducted a geophysical survey of the occurrence, and outlined several mineralized zones containing zinc, lead, and cobalt.

Falconbridge Nickel Mines Limited, from 1956 to 1961, explored for massive sulphides in east-central Hart Township. The company diamond drilled 16 holes, totalling about 670 m, in a Nipissing Diabase body and in a shear zone. Only minor amounts of pyrite were encountered.

A. Lacelle, from 1961 to 1969, trenched and diamond drilled Nipissing Diabase and Huronian metasediments in south-central Hart Township. A total of about


SUDBURY
Onaping
Lake Wanapitei
Levack
Creighton
Garson
Coniston
Falconbridge
Dowling
Capreol
Chelmsford
Azilda
Hanmer
Val Therese
Lively
Whitefish
Naughton
Wahnapitae
Cartier
Verner
Vernon
Windy L.
Ramsey L.
Hart
Ermatinger
Totten
Fairbank L.
Lake Nepahwin
Lake Ramsey
Lake Penage
Lake Panache
Lake Nebonabing
Lake Nebonabing
Lake Nebonabing

518 m of diamond drilling encountered only minor disseminated pyrite.

A. Landry, in 1971, trenched and diamond drilled a nickel-copper showing in north-central Hart Township. In 1972, the claims were optioned by Jar Vin Magnetite Syndicate. This company carried out further trenching and put down 5 diamond-drill holes totalling more than 200 m.

Hollinger Mines Limited, in 1977, conducted a ground magnetometer and geological survey near the northern township boundary in Hart Township, and in south-central Moncrieff Township.

In 1979, BP Minerals Limited conducted a radiometric and geological survey of its claims in west-central Hart Township. Except for a few radioactive quartz monzonite boulders, nothing of significance was discovered.

In Ermatinger Township, Arcadia Nickel Corporation Limited, in 1957, diamond drilled one 365 m long hole near the southern part of the eastern township boundary.

From 1957 to 1959, Alcourt Mines Limited conducted some trenching and sampling near the Huronian basement contact in north-central Ermatinger Township. Subsequently, the company put down 5 diamond-drill holes totalling about 378 m. No further work was performed due to the lack of a stable uranium market at that time. Later, in 1967, Balboa "U" Mines Limited conducted a ground radiometric survey of the area and discovered a uranium-thorium anomaly. Subsequently, 3 diamond-drill holes, with an aggregate length of about 545 m in the anomaly returned only minor amounts of U_3O_8 and ThO_2.

In 1974, Consolidated Morrison Explorations Limited conducted an aeromagnetic and an airborne radiometric survey in north-central Ermatinger and adjoining Hart Townships. No significant anomalies were encountered.

There are no records indicating any exploration activities in Totten Township.

General Geology

The bedrock in the map-area can be divided into 4 main groups: Early Precambrian gneissic and migmatitic rocks, felsic plutonic rocks, Middle to Late Precambrian (Proterozoic) Huronian sediments, and post-Huronian mafic intrusive rocks.

The Early Precambrian gneissic and migmatitic rocks are exposed in northeastern Totten and northwestern Hart Townships. They consist of highly deformed and metamorphosed rocks with prominent mafic to felsic gneissic layering. The mafic layers consist of alternating dark grey and grey coloured bands which contain variable amounts of hornblende, plagioclase, quartz, and biotite. They are dioritic to tonalitic in composition. The felsic layers, granodioritic to tonalitic in composition, and consist of quartz, plagioclase, biotite, hornblende, and potassium feldspar. These gneissic and migmatitic rocks are intruded by massive to foliated quartz monzonite and related phases, mafic dikes, and breccia dikes.

Two distinct felsic plutonic rock suites can be recognized in the area, and they are:

1. A massive to foliated, in places sheared, pink to pink grey and grey, older suite of fine and medium- to coarse-grained, rarely porphyritic quartz monzonites, granites, granodiorites, and related segregated and intrusive pegmatites and aplite dikes (Birch Lake Batholith of Card and Palonen 1976).
2. A massive, pink coloured, locally cataclastically deformed younger suite of coarse-grained porphyritic quartz monzonite and granite, fine- to medium-grained leucocratic quartz monzonite, and related segregated and intrusive dikes of pegmatites and aplites (Cartier Batholith of Card and Innes 1981). This younger suite of felsic plutonic rocks exhibits intrusive to gradational contacts with the above Birch Lake Batholith.

Rocks of both batholiths consist of potassium feldspar, plagioclase + quartz ± hornblende ± biotite. The plagioclase to potassium feldspar ratio in the Birch Lake Batholith varies roughly from 2:5 to 5:3, while it appears approximately constant at 3:5 in the Cartier Batholith. Old diabase dike swarms intrude both batholiths.

Resting unconformably on an irregular erosion surface is a sequence of Huronian sediments. The oldest Huronian sedimentary rocks in the map-area are arenites of the Mississagi Formation (Hough Lake Group). The formation consists of an approximately 150 m thick, fining upwards sequence of medium- to coarse-grained quartz-rich sandstone with rounded quartz clasts; green to pink weathering quartzite with silty partings; and rusty brown weathering dirty sandstone with graded bedding.

Approximately 150 m of light grey to rusty weathering paraconglomerate of the Bruce Formation overlies the Mississagi Formation. The contact between the two formations is abrupt and conformable. The conglomerate has granitic and quartz clasts in a matrix of medium-grained dark grey pyritic wacke. In north-central Hart Township, Bruce conglomerate unconformably overlies granitic basement.

The Espanola Formation is, on the average, about 45 m thick in north-central Hart Township, and about 400 m thick in south-central Hart and north-central Ermatinger Townships. No contact with the underlying Bruce Formation was observed. The formation consists of, from bottom to top: alternating dolostone and siltstone; brecciated silty wacke and mudstone layers with disrupted bedding and cross lamination; massive to laminated calcareous sandstone and silty wacke; interbedded grey and pink, fine-grained quartz-feldspar sandstone and silty wacke with interlaminated and gradational calcareous beds and sand lenses; and laminated to cross-laminated pyritic mudstone and laminated quartz-feldspar sandstone. The quartz-feldspar sandstone of the Espanola Formation grades upwards into pink arkosic rocks of the Serpent Formation. The latter is about 600 m in maximum thickness in the map-area. It consists of, from bottom to top: massive arkose, quartz feldspar sandstone and laminated sandstone; orthoconglomerate with sub-

rounded to rounded granitic clasts; paraconglomerate with medium-grained greywacke matrix; and calcareous sandstone and pebbly sandstone.

The Gowganda Formation in western Hart Township rests unconformably on granitic basement rocks. In south-central Hart and north-central Ermatinger Townships, it overlies the Serpent Formation. The contact between the two formations appears to be gradational. The maximum thickness of the Gowganda Formation is about 900 m in the map-area. From bottom to top, the formation consists of polymictic orthoconglomerate and lenses of paraconglomerate in a dark grey coarse- to medium-grained wacke matrix; interbedded sandstone and siltstone with scattered clasts; wacke and pebbly sandstone; and quartz feldspar sandstone.

The Lorrain Formation conformably overlies the Gowganda Formation and is divisible into medium-grained quartz-rich pebbly sandstone; green-weathering medium-grained sandstone with well rounded quartz clasts up to 1 cm in diameter; and reddish brown to hematitic sandstone with matrix- and clast-supported conglomerates containing granitic clasts.

In west-central Hart Township, an approximately 50 m thick unit of paraconglomerate of the Lorrain Formation rests on basement granitic rocks. The polymictic conglomerate is unsorted and consists of subangular to subrounded clasts, up to boulder size.

Nipissing Diabase forms sills, dikes, and irregularly shaped bodies and consists of fine- to medium-grained diabase with chilled margins; coarse-grained, dark green diorite and gabbro with up to 5 mm long hornblende crystals.

All of the above rocks are cross-cut by dikes and irregular bodies of Sudbury-type breccias (pseudotachylite breccia) which range from veinlets to 5 m thick dikes.

A dark brown weathering dike of olivine gabbro some 40 m wide intrudes the Nipissing Diabase and older rocks.

Structural Geology

The Huronian sediments have been tectonically deformed but the intensity of deformation varies considerably from place to place. The sediments in northern Hart Township have been folded into a syncline with steeply dipping limbs. Sediments in west-central Hart Township were apparently not affected by folding and the rocks, in general, dip 15° west.

Faults in the area strike northeasterly, northwesterly, and north-northwesterly. Movements along these faults are reflected in bedding attitudes of Huronian sediments in south-central Hart and north-central Ermatinger Townships. Beds are overturned at a few localities.

Foliation in the older Early Precambrian felsic plutonic rocks is highly erratic and probably has been disturbed by the implacement of the younger felsic plutonic rocks. Gneissossity in the Early Precambrian gneissic and migmatitic rocks is highly irregular, strikes northeasterly to southeasterly, and dips vertically to subvertically.

Economic Geology

Copper-lead-zinc, uranium-thorium, and nickel-copper mineralization have been the target of mineral exploration in the map-area. Zinc and minor copper, lead, cobalt, and nickel occurs within contact metamorphosed rocks of the Espanola and Serpent Formations near the contact with Nipissing Diabase in north-central Hart Township. The minerals present include magnetite, pyrite, chalcopyrite, sphalerite, galena, cobaltite, and smaltite. Exploration by Mogul Mining Corporation Limited in 1955 and by Salem Exploration Limited in 1965 has outlined several, up to 1.4 m thick, zones of mineralization containing 1.46 to 8.06 percent zinc, 0.11 to 1.3 percent lead, 0.03 to 0.12 percent copper, and up to 0.02 percent cobalt (Resident Geologist's Files, Ontario Ministry of Natural Resources, Sudbury).

Basal siltstone and sandstone of the Mississagi Formation host uranium-thorium mineralization. Exploration including surface trenching and diamond drilling by Alcourt Mines Limited from 1957 to 1959, and Balboa "U" Mines Limited in 1967 indicate that a "greasy looking yellow-green quartzite and grey siltstone" contains traces to 0.02 percent U_3O_8, and 0.02 to 0.06 percent ThO_2 (Assessment Files Research Office, Ontario Geological Survey, Toronto).

The Nipissing Diabase in north-central Hart Township contains minor sulphide mineralization (trace to minor amounts of nickel and copper).

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No. S5 Footwall of the Sudbury Igneous Complex, District of Sudbury

Burkhard O. Dressler[1]

THIS PROJECT WAS FUNDED BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS THROUGH THE NORTHERN ONTARIO GEOLOGICAL SURVEY (NOGS) PROGRAM.

Introduction

During the last year of a 4-year project initiated in 1979 (Dressler 1979, 1980, 1981b), the author studied the footwall and the sublayer of the Sudbury Igneous Complex in an area extending from the Lockerby Mine to the Falconbridge Mine along the South Range of the Complex. Also reinvestigated were several localities at the southwestern and eastern Footwall/Complex contact. The project involves a study of the structure, metamorphism, and petrology of the footwall and sublayer rocks. Its aim is to better understand the origin of the Sudbury Structure, including its mineral deposits.

The investigations are coordinated with a detailed multi-year mapping program along the North Range of the Igneous Complex (Muir 1979, 1980; Dressler 1981a; Lafleur 1981; Choudry, this volume).

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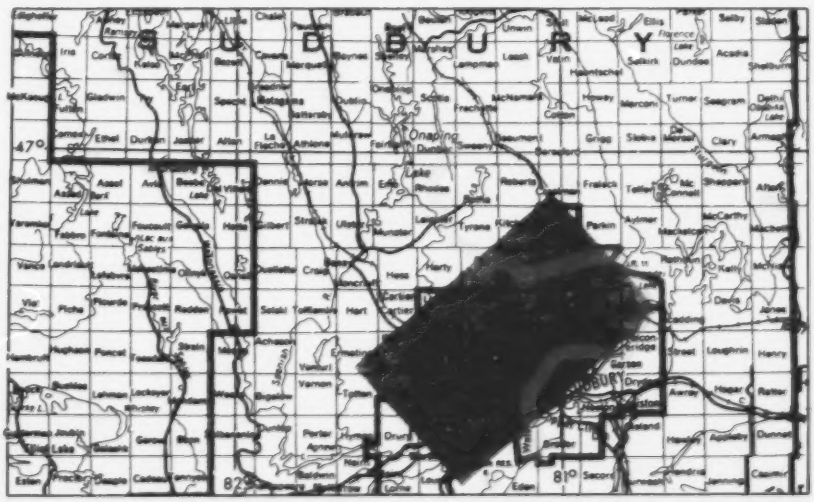
Field Investigations

During the 1982 field investigations, the author placed emphasis on the following sub-projects.

Detailed Investigation and Mapping of the Igneous Complex/Footwall Contact Between Lockerby and Falconbridge Mines

Along this contact, the relationship of the Murray and Creighton Granites with the norite of the Igneous Complex was studied. Many rock specimens were collected for petrographical and geochemical investigations. Preliminary field observations suggest that the contradicting relationships along this contact—that is, norite intruding the granites and vice versa—are best explained by assuming a contact metamorphic remobilization of the granitic rocks with subsequent injection of the granitic mobilizate into the sublayer and/or the norite.

Some of the small, square, metre-sized granitic rock exposures along the South Range Footwall/Igneous Complex contact may very well represent strongly recrystallized and remobilized footwall breccia (leucocratic



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

breccia, in the pre-1982 nomenclature). Such exposures contain many small, hardly recognizable, ghost-like rock inclusions.

Near Creighton Mine, a very fine-grained, grey rock is exposed at the sublayer ("igneous sublayer", pre-1982 nomenclature) /footwall contact that resembles the melt rock of the Onaping Formation.

Study of the Sudbury Breccia

The author studied in detail several breccia occurrences in the South Range Footwall rocks. Many specimens of breccia matrix and of host rocks were taken for geochemical investigations and for comparison with samples collected in previous years.

A few of the larger breccia bodies in the well exposed South Range Footwall rocks were mapped and sampled in great detail. The most extensive Sudbury breccia body is the one that appears to host the Stobie and Frood Mine orebodies. It can be traced for a distance of approximately 11 km from the Footwall/Complex contact near Highway 69 north of the City of Sudbury to the Town of Copper Cliff (Figure 1).

Study of Contact Metamorphism and Shock Metamorphism, South Range Footwall Rocks

Approximately 50 thin sections of South Range Footwall rocks were studied under the microscope. Most contact metamorphic and shock metamorphic features appear to have been obliterated by post-Igneous Complex regional metamorphism and deformation. Only few relicts of the features common in the North Range Footwall rocks were observed.

Study of the South Range Sublayer

Many specimens were taken for petrographical and geochemical investigations. The sublayer was also studied to compare the inclusions in the "common igneous sublayer" (Dressler 1981b) of the South Range with the inclusions in sublayer occurrences of the North and East Ranges. Preliminary results indicate that the inclusion population of the North Range "common sublayer" is somewhat different from that of the South Range sublayer.

Near the Creighton Mine, the following norite-sublayer-footwall intrusive relationships prove the post-norite age of the sublayer:

1. Elongate inclusions and matrix plagioclase laths in the sublayer are oriented parallel to the norite/sublayer contact.
2. In two places, the sublayer forms "internal offsets", 2 to 14 m wide, intruding the norite.

A sublayer outcrop west of Little Stobie Mine shows two "common sublayer" phases both enclosing norite inclusions. "Common sublayer I" intrudes norite and is intruded by "common sublayer II" which, in turn, is intruded by remobilized granite.

Economic Geology

One of the major aims of the present investigation is to obtain a better understanding of the origin and controls of mineralization environments of the Sudbury Intrusive Complex. It is, however, beyond the scope of this summary report to decribe the geology of the many mines of the areas investigated during the 1982 field season. The

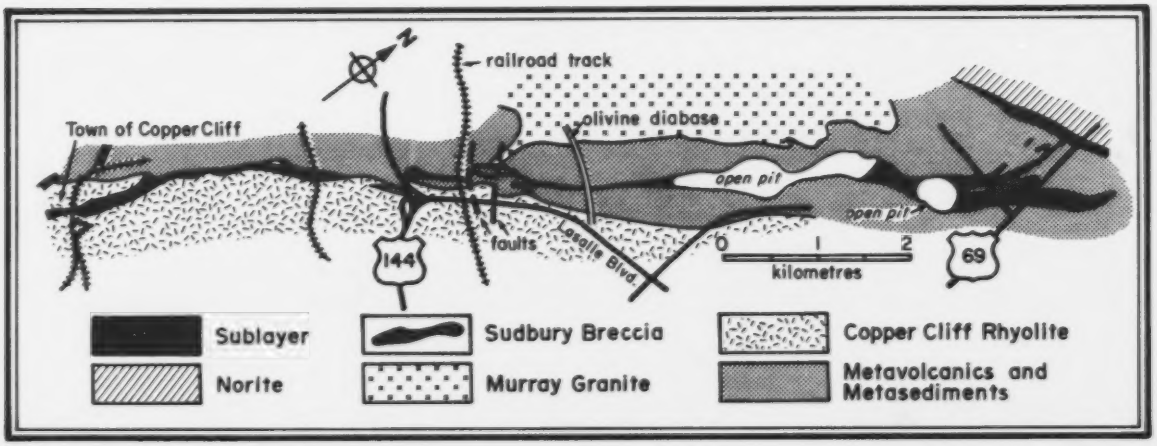


Figure 1—Sudbury Breccia dike extending from Highway 69 north of Sudbury to the Town of Copper Cliff. The Frood and Stobie Mines' open pits lie within the breccia dike.

reader is referred to Pattison (1979) for a description of the sublayer, the ore-bearing rock unit of the Sudbury Mining Camp. In Pattison's publication, references on more recent studies of the Sudbury economic geology can be found.

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No. S6 Geology and Origin of the Onaping Formation

T.L. Muir[1]

THIS PROJECT WAS FUNDED BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS THROUGH THE NORTHERN ONTARIO GEOLOGICAL SURVEY (NOGS) PROGRAM.

Introduction

The Onaping Formation is the lowermost formation of the Whitewater Group and lies entirely within the elliptically shaped Sudbury Basin which has dimensions of 52 by 18 km and is centred approximately 19 km northwest of Sudbury. The Onaping has been intruded at its base by granophyres of the Sudbury Igneous Complex and is gradationally overlain by slates of the Onwatin Formation. The Onaping comprises a number of heterolithic breccias with minor intrusive and extrusive bodies. Its origin is contentious and may be that of a fallback breccia from a meteorite impact, or a volcano-tectonic structure, or both.

Work for this project is intended to supplement recent mapping in the Sudbury area by the Ontario Geological Survey and will form part of a chapter on the Geology of the Onaping Formation which is to be included in a multi-author, special publication on Sudbury Geology, scheduled to be published by the Ontario Geological Survey in late 1984. Most of the work done this field season was in the South Range of the Sudbury Structure; a significant amount of time was also spent in the East Range.

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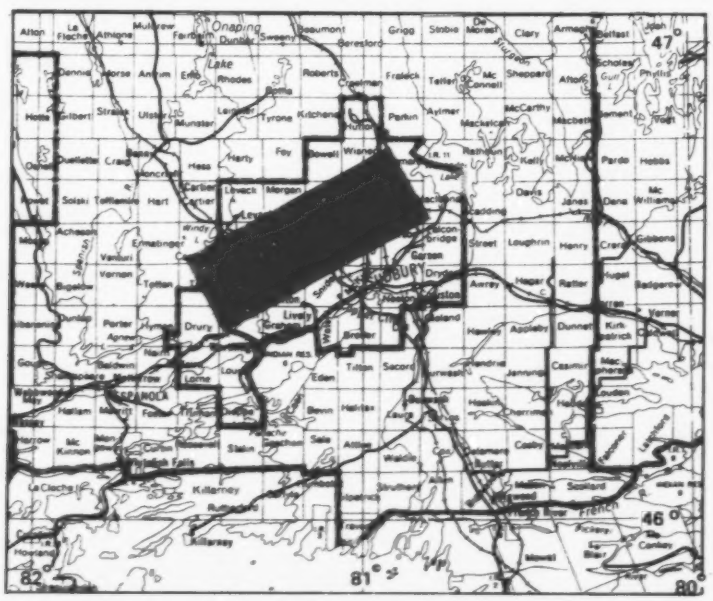
Mineral Exploration

Mineral exploration in the Onaping is not very well documented, but sulphide occurrences within the basin were noted as early as 1890; a few pits have been observed by the author during mapping initiated in 1979. Rousell (1981) stated that a number of reports of disseminated sulphides are recorded in the literature. Sulphides occur as fragments and blebs of pyrrhotite, chalcopyrite, pyrite, and sphalerite, and less commonly, as sphalerite-galena-bearing veinlets. During the last 35 years, particularly in the 1950s and 1960s, diamond-drilling by Inco Limited



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

and Falconbridge Nickel Mines Limited has been undertaken to examine conductors. No significant sulphide mineralization is recorded in the assessment files. The author is not aware of any mineral exploration within the Onaping Formation during the past field season.

The Vermilion Member of the Onwatin Formation locally lies above the Onaping-Onwatin contact and is host to zinc-copper-lead sulphides locally in Fairbank, Creighton, and Balfour Townships. Sulphide ores have been extracted from 4 mines within the Vermilion Member. Recently, the old Vermilion Mine Deposit was being re-evaluated by Giant Yellowknife Mines Limited.

General Geology

Burrows and Rickaby (1930) undertook the first significant description of the Onaping Formation and interpreted the rocks to be volcanic fragmentals and lavas. Further work was not undertaken until the 1950s when Thompson (1957) and Williams (1957) proposed a volcanic model involving Pelean domes, glowing avalanche deposits, and flows. Dietz (1962) proposed that the Sudbury Basin was the result of a meteorite impact, and French (1972) and Peredery (1972) examined parts of the Onaping to elaborate on the concept that the Onaping was the resulting fallback breccia. Still others, such as Stevenson (1972) maintained a volcanic origin and suggested that the Onaping is composed of a number of large ash-flow sheets.

In 1979, the Ontario Geological Survey began a multi-year program to map parts of the Sudbury area, particularly in the area of the North Range. As part of the map-areas, the author reported on the Onaping Formation and treated it largely as a volcanic product (Muir 1981a) with initial impact products (Muir 1981b, in press). Lafleur (1982a, 1982b, 1982c) continued the mapping program and favoured a volcanic origin. The author currently favours an origin of impact followed by the induced volcanism, but believes that the issue is far from settled.

The Onaping Formation can be subdivided into three members plus an igneous-textured component. The lowermost basal member comprises various breccias composed largely of fragments of meta-arkose and quartzite in the South Range and granitic and metasandstone fragments in the North Range. The overlying grey member comprises a number of units of heterolithic breccia which resemble pyroclastic rocks. The uppermost black member also comprises a number of poorly defined units of heterolithic breccia which resemble pyroclastic rocks in the lower two-thirds but which tend to exhibit sedimentary characteristics in the upper third. The Onaping igneous-textured component, termed Onaping melt, comprises igneous-textured bodies and closely associated aphanitic flow-banded bodies which contain fragments of meta-arkose and quartzite, and which occur within all three members, although mostly near the basal member-grey member interface. Significant variations in lithological characteristics occur within all of these major units.

Several significant features of the Onaping Formation are:

1. Contacts between small-scale units within the grey and black members were delineated by the author this past summer in the East and North Ranges, indicating that the Onaping is not a simple deposit (Figure 1).
2. These contacts show significant changes in direction; there is no evidence for folding and there are no large relief features which would account for the irregular contacts on outcrop. This suggests that there was significant relief at the time of deposition of the small-scale units (Figure 1).
3. Contacts between small-scale units on a northeast-facing slope in the East Range suggest that some units are dipping away from the centre of the basin (Figure 1).
4. Individual units are generally discontinuous but may be present elsewhere along strike (Figure 1).
5. Well developed bedding, noted in the middle third of the black member, has a strike that is approximately at right angles to the regional trend.
6. Composite fragments, with up to three ages of brecciation which locally show 'bedding', suggest that multiple events took place during the formation of the Onaping.
7. Crystalline phases representing primary magmatic material do not appear to be present.
8. The presence of phenocrysts is equivocal.
9. Up to 3 types of glassy fragments may be present on a hand-specimen scale.
10. Shock metamorphic features can be found throughout the Onaping within fragments of basement rocks.
11. Sulphide ore fragments in the Onaping indicate that a sulphide body (bodies) existed at the time of the explosive activity.

Structural Geology

Much of the Onaping Formation in the North Range and the East Range has not been significantly affected by deformation except in shear zones within the upper part of the exposed black member. The Onaping Formation in the South Range is generally significantly deformed and locally recrystallized. A well developed, moderate to steeply south-dipping schistosity with steeply plunging lineations (stretched fragments), and local crenulations and kink bands is apparently the result of a push from the south during the Penokean and/or Grenville Orogenies. Concomitant reverse faulting and folding also occurred and have locally complicated the simple configuration of the three-member formation, particularly in the southwestern and southeastern ends of the Sudbury Basin.

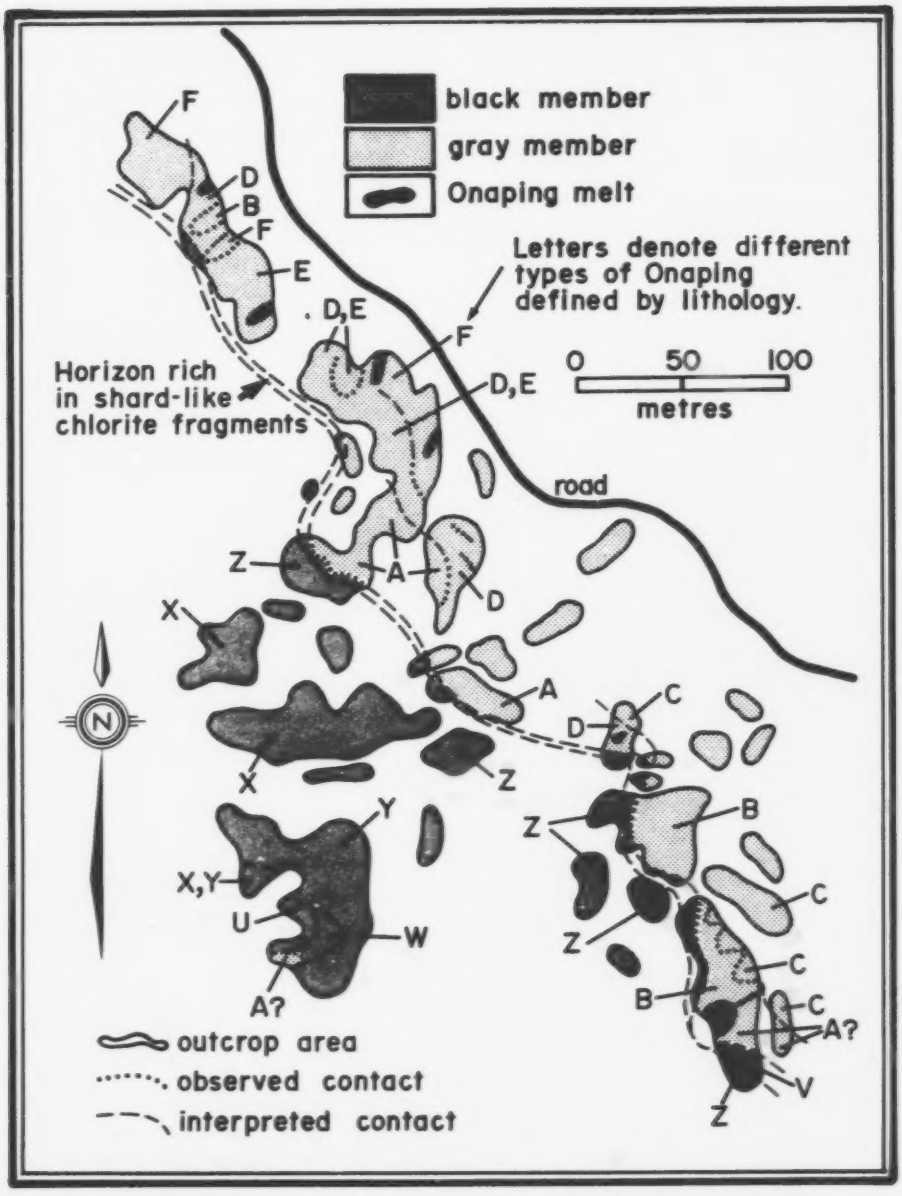


Figure 1—Preliminary geological sketch map of part of the Onaping Formation in the East Range of the Sudbury Structure.

Economic Geology

The Onaping Formation, compared to rocks of similar overall composition, is anomalous in copper, platinum, and palladium, and somewhat in nickel content (Rousell 1981; Muir, in press). These elements are associated with heterogeneously dispersed fragments and blebs of sulphide mineralization from about 1.5 cm to less than 0.2 mm long. The sulphide ores, consisting of pyrrhotite, chalcopyrite, pyrite, and sphalerite, also occur within glassy fragments, gabbroic fragments, and quartzose fragments, as well as rims on quartzose fragments and along hairline fractures in the matrix.

Sulphide ores within the chert-carbonate-bearing Vermilion Member, which lies on top of the Onaping Formation, are lead, zinc, copper, and silver-bearing (Rousell 1981). Milling problems (circa late 1950s) with the ore from 4 mines within this member were instrumental in their closing, but the mineralization was not exhausted (Rousell 1981). A hydrothermal system generated by the contained heat from the Onaping Formation at the time of its deposition, or from the intrusion of the Sudbury Igneous Complex, or both, may have been significant methods in remobilizing some of the metals present within sulphide fragments in the Onaping. The Vermilion Member is certainly a logical exploration target.

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No. S7 Wicklow Area, Hastings County

F.W. Breaks[1] and R. Thivierge[2]

THIS PROJECT WAS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

The map-area includes Wicklow, Bangor, Sabine, Lyell, McClure, Monteagle and Carlow Townships, and is bounded by Latitudes 45°15′N and 45°22′30″N, and Longitudes 77°45′W and 73°00′W, an area of 280 km². Access is via Highways 127 and 62 which traverse through the southwestern and southeastern map corners. The Madawaska Highway and Little Papineau Lake road provide good access to the western map-area, while the West Papineau Lake-Centerview road system provides access to the north-central and northeastern parts.

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LOCATION MAP **Scale: 1:1 584 000 or 1 inch to 25 miles**

Mineral Exploration

Mineral exploration has been confined to 2 general periods and commodities: 1) circa 1900-1916 (corundum bearing syenites), and 2) mid-1950s (uranium bearing granite pegmatites). Discovery of corundum by W.F. Ferrier of the Geological Survey of Canada in 1897 in the New Carlow area (Hewitt 1955), adjacent to the southeastern corner of this report area, led to establishment of a flourishing local abrasives industry. Many occurrences were discovered in the New Carlow area in the early 1900s, including a small deposit at Hoover Mountain (Hewitt 1955). A small amount of corundum ore was mined at the Hoover Mountain Deposit in 1916 and transported to the Burgess Mine for milling (R. Armstrong, resident and former prospector, New Carlow, personal communication, 1982). A 0.7 to 1 m wide muscovite-magnetite-biotite-corundum syenite pegmatite, averaging approximately 6 percent corundum, was mined within a shallow trench (Hewitt 1955). Operations at Hoover Mountain ceased in September of 1916 due to an accident involving an explosion of a steam boiler and dynamite that resulted in the loss of several buildings and one workman's life (R. Armstrong, personal communication).

Interest in uranium-bearing granitoids developed during the early to mid-1950s, and numerous claims were staked in the Balsam Lake-Centerview area focusing upon the Dubblestein and Thomas Properties (Masson and Gordon 1981), and the James Property (C. Janes, resident, Centerview, personal communication, 1982).

Previous Work

Most of the area has remained unmapped subsequent to the work of Adams and Barlow (1910). Detailed coverage of Monteagle and Carlow Townships by Hewitt (1955) partially overlaps the southeastern corner of the map-area, while more recent reconnaissance mapping by Lumbers and Vertolli (1980) extends into the north-central to northeastern and eastern fringes. Additional current investigation in the area is being undertaken by R. Thivierge at University of Ottawa in the form of M.Sc. thesis research in the Centerview-Combermere area, and by W. Miller of Queen's University who is examining the unique cordierite ortho-amphibole-orthopyroxene-garnet gneisses in the Hoare Lake area near the eastern boundary of the map-area.

Recent reconnaissance of radioactive mineral occurrences in the Bancroft region has been conducted by Masson and Gordon (1981).

Geology

The map-area features an important contact between the Grenville Supergroup and a gneissic melange of intermediate composition and higher metamorphic grade belonging to the Madawaska Highlands Gneissic Complex. Grenville Supergroup lithologies are localized within the Carlow Synform (see section on Structure) and confined to a narrow arch outlining the periphery of this major fold. This metasedimentary package is comprised of graphite ± phlogopite-diopside and scapolite-diopside marbles, fine- to medium-grained plagioclase ± biotite-quartz-potassium feldspar psammitic metasediments, marble tectonic breccia, graphite-biotite-garnet-plagioclase metapelite, and rare amphibole-bearing quartzite and paraamphibolite. These rocks are intruded by undersaturated to quartz-bearing syenitic rocks herein termed the "New Carlow Syenite Complex". This complex, renowned for spectacular corundum-rich pegmatites, constitutes a very complicated, generally interlayered, and variably metamorphosed-deformed plutonic assemblage comprised of at least 8 distinct phases as summarized below:

1. diorite-syenodiorite (CI 40-60)
2. biotite ± muscovite ± magnetite syenite (CI < 10)
3. magnetite-biotite plagio-syenite (CI < 10)
4. corundum-bearing syenites
   a) biotite ± corundum ± muscovite syenite (CI 15-20)
   b) muscovite-magnetite-biotite-corundum plagiosyenite to monzonite (CI < 5)
   c) muscovite-corundum-biotite syenite (CI 5-10, corundum content <5 percent; appears gradational into 4b)
6. diopside ± sphene syenite to monzonite (coarse-grained to pegmatitic, CI < 10)
7. diopside ± sphene syenite to monzonite (CI 3-10; in narrow dikes in exocontact skarns and Grenville Supergroup metasediments)
8. quartz-bearing biotite syenite to monzonite (CI < 5)

Contact of this unit with carbonate-rich metasediments is marked by calc-silicate skarn development, typically containing diopside, actinolite, ± scapolite, phlogopite-garnet-augite-sphene-hornblende. Skarn assemblages are also distributed randomly throughout the complex particularly in association with phase 6.

Madawaska Highlands Gneissic Complex

A melange comprised mainly of migmatized supracrustals, diorite to quartz diorite-tonalite orthogneiss, dominates the map-area. The degree of tectonic deformation, recrystallization, and migmatization is generally quite extensive except in the Little Papineau Lake stock.

Overall, an intermediate bulk composition probably typifies this gneissic complex. Mafic to intermediate metaplutonic rocks are found in the Little Papineau Lake stock near the Little Papineau Lake-Morris Pond area. This apparent comagmatic suite consists mainly of weakly to moderately deformed, incipiently migmatized, medium-grained biotite-hornblende diorite and subordinate ± hornblende-biotite diorite to leucocratic quartz diorite and biotite trondhjemite. Thin sheets of metamorphosed biotite to biotite-hornblende granite, up to 30 m in thickness, biotite trondhjemite, and unmetamorphosed allanite-magnetite-biotite granite pegmatite dikes of the northeast-striking Hybla swarm cut the stock. Metasedimentary migmatite, classified according to Breaks *et al.* (1978), is confined to definite belts, for example the Furz Mountain-Centerview-Balsam Lake area, and is interlayered in part with trondhjemitic gneiss. Metatexites within this belt and in the McKenzie Lake area are typified by 10 to 20 percent coarse-grained trondhjemite leucosome, hosted within fine-grained ± garnetiferous metawacke and/or biotite ± hornblende metapelitic paleosome. At Furz Mountain, an undoubted metasedimentary succession, 240 m thick, is enclosed within trondhjemitic gneisses. The metatexites are frequently diablastic with idiomorphic to subidiomorphic potassium-feldspar and plagioclase megablasts commonly in 1 to 3 cm diameter range and comprising up to 40 percent of the paleosome. These diablastic rocks are spatially related to zones of high strain and may serve to delineate such zones.

Many of the biotite-rich, quartzo-feldspathic gneisses in the Purdy-Maple Leaf area (Highway 62) are suspected derivatives of metasedimentary migmatites converted to nebulitic and/or hamophorous types through advanced paleosome blastesis, increasing anatexis and tectonic reduction of leucosome grain size (Mehnert 1971, p.40-42).

Tectonic breccias in several localities are inclusion-laden units with a coarse-grained, blastic biotite granite medium containing a fragment population of amphibolite, dioritic rocks, biotite trondhjemite, and are skarns or anorthositic gabbro. The best examples occur near the eastern shoreline of Papineau Lake in the vicinity of Poplar Pond, 1 km northwest of Yuill Lake, and on Madawaska Highway near Evans Lake.

The units are late, cross-cut regional units, and are difficult to correlate within the map-area.

Metamorphosed potassic granitoid suite rocks are commonly interbanded within biotitic quartzofeldspathic gneisses and orthogneiss often forming erosional remnants capping hill summits in the Lake Papineau area.

The Hybla pegmatite swarm is weakly evident within the map-area.

Structural Geology

All rock types in the area, with the exception of late dikes,

TABLE 1 SUMMARY OF MESOSCOPIC HIGH GRADE TO GRANULITE REGIONAL METAMORPHIC MINERAL ASSEMBLAGES DEVELOPED IN SELECTED LITHOLOGIES FROM THE WICKLOW AREA

METAMORPHIC GRADE	LITHOLOGY	ASSEMBLAGE	RETROGRESSIVE MINERAL(S)
I. High Grade	Metawacke	±hb-bio-q-plg	Chlorite locally
	Metawacke	gt-bio-q-plg	Chlorite locally
	Metapelite	q-sill-gt-bio-Kfel-plg	Chlorite locally
	Metapelite	±hb-q-bio-plg	Chlorite and/or Epidote locally
	Amphibdite	±bio±q-hb-plg	Chlorite locally
	Metapelite	±py-q-gf-bio-gt-Kfel-plg	
II. Granulite Grade	Anatectic Pods in Amphibolite	±q±bio-diop-Opx-plg	Hb mantles diop and/or Opx
	Anatectic Pods in Metadiorite	±q-diop-Opx-plg	Hb mantles diop and/or Opx
	Anatectic Pods in Metagabbro	±q±gt-diop-Opx-plg	Hb mantles diop and/or Opx
	Anatectic Pods in Metapelite	±Kfel±q±mag-Opx-plg	Local chlorite
	Trondhjemite	Opx-q-bio-plg	
	Hoare Lake Gneisses	±q±plg-bio-ct-Oamp-Opx	
		±q±plg-bio-Oamp-gt	
		plg-q-gt-Opx	
		plg-q-gt-Opx-Oamp	
		±q-gt-bio-plg	
		bio-q-ct-gt-plg	
		±Oamp-bio-plg-ct-gt-q	

NOTES:

bio	Biotite	mag	Magnetite
ct	Cordierite	Oamp	Orthoamphibole
diop	Diopside	Opx	Orthopyroxene
gf	Graphite	plg	Plagioclase
gt	Garnet	py	Pyrite
hb	Hornblende	q	Quartz
Kfel	Potassium feldspar	sil	Sillimanite

reveal a protracted tectonic history, featuring at least 4 regional folding events. Early folds are rarely identified except as isoclinal, refolded mesascopic folds in gneisses with metamorphic segregation layering (likely "Elsonian" granulite-facies, based on 1430 Ma Rb-Sr whole-rock isochron of Bell and Blenkinsop (1980)). These features are modified into conformity by the second event. Early folds within layered Grenville Supergroup metasediments, refolded by the second deformation, cannot be synchronized with those in the gneisses.

Asymmetric polyclinal folds are plunging gently west or southwest within well banded gneisses in the northeastern map-area. These may correspond to the early folds of Appleyard and Stott (1975).

The second or "Grenville" deformation, ("Ottawan orogeny" of Moore (1982) at about 1100 to 1050 Ma) involves high-grade metamorphism, anatexis, and granitoid (and basement?) mobilization. It imposed a penetrative L-S metamorphic fabric and a broadly northeast-striking macroscopic first-order structural trend with dips between 10° to 40°SE. The Grenville "A" lineation (Hewitt 1962) plunges shallowly toward the southeast, generally down-dip in foliation surfaces. It is traceable southward to near the sillimanite isograd of amphibolite facies Central Metasedimentary Belt rocks where the L-S fabric changes in areal aspect owing to different dynamics of deformation (Divi and Fyson 1973).

Typical folds of this event are mesoscopic, asymmetric, and tight to isoclinal with an axial planar fabric and axial lineation. Thivierge (1982) notes that they are reclined to the northwest and commonly display vergence to the northeast, and suggests that before later deformation the foliation was shallow-dipping to subhorizontal.

Local areas of relatively high strain display isoclinal, intrafolial or transposed folds, sheath folds, sigmoidal augen, mafic tectonic breccia, and protomylonitic to mylonitic textures. Davidson *et al.* (1982) term these features "tectonite gneiss zones" bounding regional lithostructural domains in the western Ontario Gneiss Segment.

A third major folding is macroscopic, essentially upright and open southeast-plunging folds coaxial with the mineral lineation which fold the Grenville Supergroup rocks in the herein defined "Carlow synform", whose axial trace runs from the southwestern Papineau Lake area across Carlow Township, where it folds the Boulter pluton. Northwest-trending gneissosity forms second-order structural trends, considered to represent this episode of folding. In the Barry's Bay-Palmer Rapids region possibly complementary(?) major folds influence only basement gneisses and are reclined to the northeast (Brock 1982).

A fourth folding event involves mesoscopic east-trending subhorizontal warping about shallow-plunging axes. Folds are upright to reclined.

Metamorphism

Most of the map-area is of high-grade metamorphic facies (Winkler 1979). Locally, granulite grade is attained. Orthopyroxene-bearing rocks (Table 1) are between Papineau Lake, Highway 62, Latitude 45°15′ and Longitude 78°00′. The highest modal abundance is in the Hoare Lake gneisses with coexisting pyroxene-, cordierite-, orthoamphibole, and garnet (Table 1). These gneisses are contained within biotite, garnet-biotite, and sillimanite-garnet-biotite-bearing migmatized metasediments, traceable over a strike length of 240 m and width of 200 m.

Economic Geology

Uranium mineralization is developed in 3 separate granitic pegmatites in the Balsam Lake area and was investigated in the mid-1950s by E. Dubblestein, C. Gagnon, C. James (Dubblestein and James Occurrences), and by A. Thomas (Thomas Occurrence). Five grab samples from the James Occurrence submitted in 1955 indicated *nil* to 0.01 percent U_3O_8 and high trace levels of zirconium were found in one specimen (C. James, resident, Centerview, personal communication, 1982).

The Dubblestein Occurrence consists of a flat-lying, zoned granitic pegmatite, at least 6.5 m in thickness, and with an approximately 30 m strike length (Masson and Gordon 1981).

High uranium mineral analyses of 6.36 and 8.63 percent U_3O_8 were obtained. However, these assays may, in part, relate to fergusonite, which was tentatively identified by this survey and may serve to more fully explain high trace levels of niobium and cesium in the semiquantitative emission spectrographic analyses.

The Thomas Occurrence was investigated in 1955 by trenching and diamond-drill holes (Masson and Gordon 1981, p.29). The highest radioactivity occurs within a 1.5 by 1.75 m hematized zone of steeply dipping pegmatite. Up to 10 percent allanite, with coarse-grained magnetite and thorite, are within a quartz-poor hematized zone with 540 ppm U_3O_8 and 1.7 percent thorium (Masson and Gordon 1981). Sulfide mineral concentrations are very sparse since the map-area is principally underlain by sialic gneiss.

Subeconomic quantities of molybdenite were observed in:

1. metasedimentary migmatite association on the western shoreline of Papineau Lake. Molybdenite in paleosome occurs as linear aggregates up to 6.5 by 0.5 cm
   a) in a medium-grained nebulitic leucosome on the largest island in Balsam Lake
2. granite dikes
   a) in a zoned granite dike in metagabbro (Highway 62, 1.7 km southwest of Maple Leaf)
   b) in a pyrite-bearing granite dike (roadcut near the end Balsam Lake)
3. syenite association
   a) fine-grained disseminated MoS_2 white diopside syenite on Highway 62, 1.8 km east of Maple Leaf

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No. S8 Lavant Area, Frontenac and Lanark Counties

Liba Pauk[1]

THIS PROJECT WAS PART OF THE SOUTHERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

The Lavant area is located 110 km southwest of the City of Ottawa and includes parts of Lavant, Dalhousie, Palmerston, Darling, South Canonto, and Lanark Townships. The area covers about 260 km^2 and is bounded by Longitudes 76°30′W and 76°45′W, and by Latitudes 45°00′N and 45°07′30″N. It lies east of Highway 509 and west of Highway 511, and is accessible by Lanark County Road 16, a west-trending road in the central part of the map-area. The township roads, forest access roads, lumber roads, power line service roads, and snowmobile trails provide good access to all of the map-area. A large part of the area has been previously mapped at a scale of 1:63 360 by Smith (1958) and Peach (1958).

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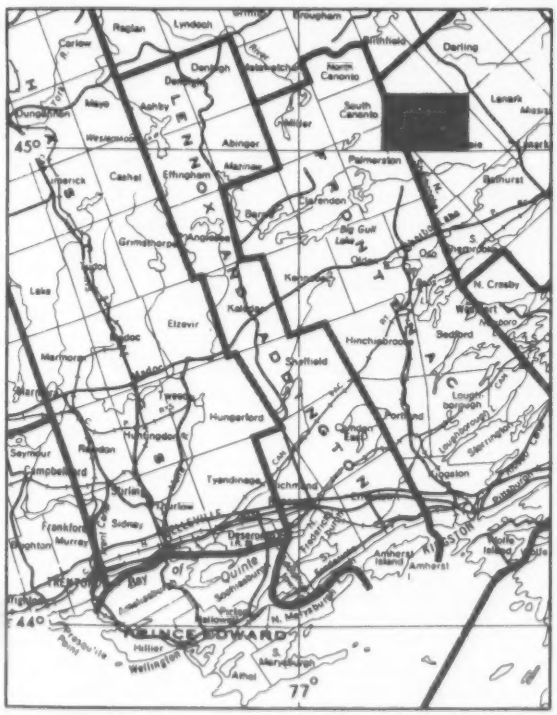
Renfrew
Lanark
Frontenac
Lennox and Addington
Prince Edward
Hastings
Peterborough
Victoria
Haliburton
Durham
Northumberland
Darling
Lavant
Palmerston
Dalhousie
South Canonto
Bathurst
Sheffield
Hinchinbrooke
Portland
Kingston
Amherst Island
Amherst
Quinte
Bay of
Napanee
Belleville
Trenton
Brighton
Wellington
Picton
Consecon
Colborne
Cobourg
Port Hope
Bowmanville
Oshawa
Whitby
Pickering
Toronto
Scarborough
Markham
Uxbridge
Stouffville
Newmarket
Aurora
Richmond Hill
Vaughan
Woodbridge
Brampton
Georgetown
Milton
Oakville
Mississauga
Hamilton
Burlington
Niagara Falls
St. Catharines
Welland
Port Colborne
Fort Erie
Niagara-on-the-Lake
Grimsby
Lake Ontario
Lake Erie
Lake Simcoe
Georgian Bay
Lake Huron
Lake Couchiching
Orillia
Barrie
Collingwood
Owen Sound
Wiarton
Tobermory
Bruce Peninsula
Manitoulin Island
Sudbury
Parry Sound
Huntsville
Bracebridge
Gravenhurst
Muskoka
Algonquin Park
Pembroke
Petawawa
Deep River
Chalk River
Arnprior
Carleton Place
Almonte
Perth
Smiths Falls
Brockville
Gananoque
Cornwall
Alexandria
Hawkesbury
Ottawa
Kemptville
Merrickville
Prescott
Morrisburg
Iroquois
Ogdensburg
Massena
Watertown
Kingston
Rideau Lakes
Big Gull Lake
Clyde Forks
Robertson Lake
N. Crosby
S. Crosby
Sydenham
Westport
Newboro
Seeley's Bay
Elgin
Delta
Athens
Lyndhurst
Gananoque
Rockport
Thousand Islands
Wolfe Island
Howe Island
Cape Vincent
Sackets Harbor
Henderson Harbor
Pulaski
Oswego
Syracuse
Rochester
Buffalo
Niagara Falls
Toronto
Detroit
Windsor
Sarnia
London
Stratford
Kitchener
Waterloo
Guelph
Cambridge
Brantford
Woodstock
Ingersoll
Tillsonburg
Simcoe
Port Dover
Port Stanley
St. Thomas
Aylmer
Tavistock
Stratford
Goderich
Kincardine
Port Elgin
Southampton
Walkerton
Hanover
Durham
Owen Sound
Meaford
Thornbury
Collingwood
Wasaga Beach
Midland
Penetanguishene
Orillia
Barrie
Innisfil
Bradford
Alliston
Beeton
Tottenham
Caledon
Orangeville
Shelburne
Dundalk
Flesherton
Markdale
Chesley
Hanover
Walkerton
Wingham
Blyth
Clinton
Goderich
Exeter
Grand Bend
Forest
Petrolia
Wyoming
Sarnia
Point Edward
Chatham
Wallaceburg
Dresden
Ridgetown
Tilbury
Leamington
Kingsville
Essex
Amherstburg
Lakeshore
Tecumseh
LaSalle
Windsor
Belle River
Comber
Blenheim
Thamesville
Dunnville
Port Dover
Simcoe
Delhi
Tillsonburg
Ingersoll
Woodstock
Brantford
Paris
Cambridge
Kitchener
Waterloo
Guelph
Elora
Fergus
Orangeville
Shelburne
Alliston
Beeton
Tottenham
Bradford
Innisfil
Barrie
Orillia
Midland
Penetanguishene
Wasaga Beach
Collingwood
Thornbury
Meaford

ceous and calc-silicate sediments, and carbonate sediments is exposed in the western part of the region. These rocks have been transformed into a variety of mafic to siliceous gneisses and schists and their primary textural and structural characteristics have been largely obliterated due to the high degree of recrystallization and deformation.

The central belt of supracrustal rocks (Lavant-Darling supracrustal succession, Carter 1981) is wedged in between the Addington Complex (granite to quartz monzonite gneiss) to the west, and the Lavant Gabbro Complex to the east. The width of this belt ranges from 400 m in the south to 1600 m in the north. The rocks comprise mafic metavolcanics and intercalated carbonate metasediments, with subordinate metamudstones and clastic siliceous metasediments. A large portion of these rocks is contained within the Robertson Lake Shear Zone, and their original compositional and textural characteristics have been highly modified by shearing, fracturing, and retrograde alteration.

In the eastern part of the map-area, the supracrustal rocks form narrow bands and lenses within the Lavant Gabbro Complex. Carbonate metasediments and mafic metavolcanics are dominant. Submarine volcanism is demonstrated by the presence of highly deformed, yet identifiable pillow basalts. A sequence of fragmental, tuffaceous, and massive metavolcanics also has been documented here.

Several narrow bands of pelitic, psammitic, and calc-pelitic metasediments of the Flinton Group conformably overlie the older supracrustal rocks in the western part of the region.

The Addington Complex is a narrow 1 to 4 km wide sill-like body that extends northeasterly from the Tweed area to beyond the northern map boundary for a total length of about 100 km. It extends across the west-central part of the map-area and forms an approximately 2 km wide north-northeasterly trending ridge that is conformable with the surrounding supracrustal sequence. The rocks of the Addington Complex consist of foliated, weakly foliated to lineated biotite and muscovite granite to quartz monzonite gneisses. In the southern and particularly in the northern parts of the complex, numerous conformable layers of metasedimentary and metavolcanic gneisses and marble are present.

Fine-grained, weakly foliated to lineated muscovite and biotite granite gneiss occupies the nose of the Cross Lake Antiform. Along their southern contact, the gneisses range laterally into light gray, fine-grained biotite metasandstone.

Numerous conformable layers of pink granite gneiss are also present within the metavolcanics in the northwestern part of the area.

The Lavant Gabbro Complex occupies a prominent topographic high in the eastern half of the region. The body, generally conformable with the supracrustal rocks, extends farther to the southwest and the northeast for a total length of about 40 km. Throughout the map-area, the intrusion varies in composition and texture. Fine- and medium- to coarse-grained rocks of gabbro-diorite and granodiorite composition exhibit cross-cutting intrusive characteristics in places. Only the northwestern part of the body, comprised of fine- and medium- to coarse-grained

TABLE 1 SUMMARY OF Cu-Sb-Au-Ag DEPOSITS OCCURRING WITHIN THE LAVANT-DARLING SUPRACRUSTAL SUCCESSION (MODIFIED FROM CARTER, COLVINE, AND MEYN 1980; CARTER 1981). THE DEPOSITS ARE LISTED AS THEY OCCUR FROM NORTH TO SOUTH

DEPOSIT	NATURE OF MINERALIZATION	TYPE OF MINERALIZATION	METAL CONTENT
Joes Lake	layers, pods, and lenses of white dolomite within fine-grained dark grey dolomitic marble	disseminated tetrahedrite, chalcopyrite and pyrite, secondary malachite	Cu, Sb, Au, Hg
Lavant Creek	network of narrow quartz veins within dolomitic marble	disseminated fine-grained chalcopyrite, pyrite, secondary malachite, azurite, dendritic pyrolusite	Cu
Nelson Lakes	pods of quartz hosted by fine-grained dolomitic marble	scattered coarse grains (up to 2 cm) of chalcopyrite	Cu
Begin	quartz-rich brecciated zone within aphanitic dolomitic marble	disseminated coarse-grained chalcopyrite, less common bornite and tetrahedrite, pyrite, secondary malachite, azurite	Cu, Ag
Lavant	network of narrow quartz veinlets within dolomitic marble	sparse grains of tetrahedrite, bornite, pyrite, secondary malachite	Cu, Sb, Au, Ag
Lynx Canada	stratabound quartz vein; hosted by dolomitic marble	coarse-grained disseminated bornite, chalcopyrite; secondary malachite; quartz crystals in vugs	Cu
Robertson Lake	network of quartz veinlets and pods hosted by dolomitic marble near the contact with sheared and pyritized gabbro	disseminated pyrite and pyrrhotite	Au (Smith 1958)

pyroxenic gabbro, is compositionally more homogeneous. Primary rhythmic and graded layering of pyroxene cumulates has been observed. The Lavant Complex, in general, is structureless, except for its peripheral parts which, in places, exhibit weak foliations.

Late stage felsic intrusive phases are represented by small granite and pegmatite dikes and veins intrusive into the Lavant Gabbro Complex, and by numerous pegmatite dikes and sills that intrude the Addington Complex and the supracrustal rocks in the southwestern part of the region.

Metamorphism

In the western part of the map-area, the rocks have been metamorphosed to the upper almandine-amphibolite facies rank as indicated by the presence of sillimanite in the pelitic schists. The appearance of the sillimanite-orthoclase pair has been reported by Rivers (1976) near the Village of Clyde Forks, about 800 m north of the northern limits of the map. Within the Lavant-Darling supracrustal succession, a narrow belt of metavolcanics exhibits retrograde greenschist facies mineral assemblages, that is albite-actinolite-chlorite and albite-hornblende-chlorite (Carter 1981). The retrograde metamorphism occurs along the Robertson Lake Shear Zone and is accompanied by shearing and fracturing. As compared to the western supracrustal belt, the eastern belt of supracrustal rocks in general displays less deformation and metamorphic differentiation. Primary rock textures are better preserved. The mafic metavolcanics exhibit a mineral assemblage of hornblende-biotite-plagioclase ($>An_{15}$), characteristic of the almandine-amphibolite facies.

Structural Geology

Structurally, the map-area can be divided by the Robertson Lake Shear Zone into a highly deformed and metamorphosed western structural zone and a somewhat less deformed and less metamorphosed eastern structural zone. The structural contrast between these 2 zones, however, is not readily observable within the present map-area due to the dominance of competent intrusive rocks in the eastern part of the region. The complex structural pattern of the western part of the area can be attributed to at least 2 major periods of deformation. The first period produced isoclinal folds which display northeast-striking stratiform foliations. The second phase of deformation produced a series of northeast-trending large scale structures, namely the Clyde Forks Synform and Antiform in the northwest (Rivers 1976), the Cross Lake Antiform in the southwest (Smith 1958; Rivers 1976), and a number of smaller, poorly defined synforms and antiforms. All major first and second deformational phase structures trend northeast (N30° to 40°E). Axial plane foliations have moderate to shallow dips (60° to 20°) predominantly to the south. Shallow (10° to 30°) plunges of folds to the northeast were recorded in the western parts of the map-area.

The Robertson Lake Shear Zone is a dominant structural element of the area. It forms a prominent topographic low that passes northeasterly to northerly through the central part of the region. The width of the shear zone (400 to 1500 m) and the intensity of deformation increases from the south to the north. The shear zone contains strongly sheared and fractured metavolcanics, carbonate metasediments, and parts of the Lavant Gabbro Complex and the Addington Complex.

Economic Geology

Base and Precious Metals

Base- and precious-metal mineralization occurs within the central supracrustal belt formed by a succession of mafic metavolcanics and carbonate metasediments. A larger portion of this belt has been considerably affected by shearing, fracturing, and secondary alterations as the Robertson Lake Shear Zone passes through it. Nine small stratabound deposits of copper-antimony-gold-silver mineralization are contained within this belt over a strike length of 20 km (Carter 1981), and of these, 7 deposits lie within the present area and occur over a strike length of 9 km. The mineralization is commonly in narrow quartz veinlets, pods, and lenses, and also in silicified breccia zones, all within fine-grained, gray dolomite marble (Table 1).

The Clyde Forks Deposit, located in the northwestern corner of the map-area, lies within the thick unit of coarse-grained calcitic marble intercalated with narrow layers of biotite-carbonate gneiss and biotite-quartz-plagioclase gneiss. The mineralized zone is exposed in a small pit and a 30 m long adit. It consists of a conformable layer of coarse-grained barite, up to 1 m thick, with disseminated chalcopyrite, tetrahedrite, pyrite, and secondary malachite and azurite. Within the adit the tetrahedrite, chalcopyrite, and barite occur in pods and disseminations along the plane of foliation of the marble. Nichols (1972) recorded also the presence of stibnite, arsenopyrite, chalcostibnite, gatchellite, cinnabar, and mercurious tetrahedrite.

Reserves in this orebody are estimated to be 60 000 tons grading 13.4 pounds per ton copper, 7.5 pounds per ton antimony, 0.68 pound per ton mercury, and 1.32 ounces per ton silver (Clyde Forks Deposit, Lavant Township, Southern Ontario, Source Mineral Deposits Records, Ontario Geological Survey, Toronto).

A narrow layer of laminated muscovite metasandstone of the Flinton Group, containing small, scattered grains of chalcopyrite and coatings of malachite, has been located by field party personnel 1200 m northwest of the siding of Folger.

Magnetite

Massive magnetite occuring in a stratabound carbonate skarn has been extracted at the Wilbur Mine in the last century. A smaller, similar magnetite deposit exposed in 2 pits occurs 0.8 km west of Lavant Station.

Uranium and Thorium Mineralization

Appreciable scintillometer anomalies (3 to 6 times background) have been recorded by field party personnel in some of the pegmatite sills in the vicinity of St. Antoine Lake and Twentysix Lake in the southwestern corner of the map-area.

Non-Metallic Mineral Deposits

Good quality white pure dolomitic marble occurs in a northeasterly striking band 500 m north of the siding of Beatty.

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No. S9 Stratigraphy and Sedimentation of Carbonate Metasediments within the Grenville Supergroup in the Havelock-Madoc-Bancroft Area

Marika S. Bourque[1]

THIS PROJECT WAS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

Field work carried out during the summer of 1982 is the second phase of a project which entails an analysis of the marine system responsible for the deposition of carbonate and related clastic sedimentary rocks of the Central Metasedimentary Belt. The aim of the study is to better understand the depositional environments associated with the metasediments and to establish regional stratigraphic subdivisions. The results of this study will also have applications in adjacent parts of the Grenville Province.

The study covers an area from Belmont Lake east to Madoc and north towards Bancroft, with additional reconnaissance information from Burleigh Falls to Haliburton.

Access to most of the area is good by road or by water.

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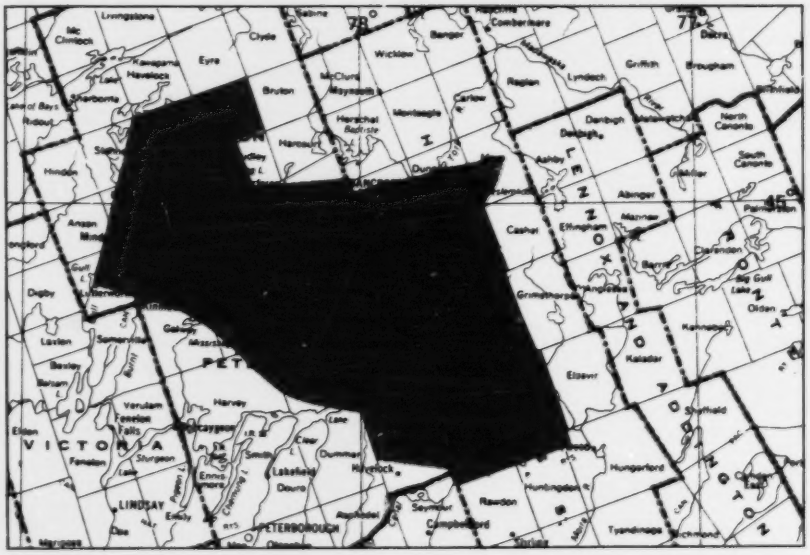
General Geology

Two major sedimentary sequences have been identified by Lumbers (1980) in the Grenville Province of Ontario, an older siliciclastic unit deposited between 2500 and 1800 million years ago, and a younger sequence deposited approximately 1500 to 1250 million years ago (Lumbers 1980). The younger sequence, the Grenville Supergroup, consists of metavolcanics, clastic siliceous metasediments, and carbonate metasediments, and is subdivided into the Anstruther Lake Group (Bright 1976),



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

Hermon Group (Lumbers 1967), Mayo Group (Lumbers 1967), and the youngest, Flinton Group (Moore and Thompson 1980).

The metamorphosed clastic and carbonate rocks in the Havelock-Bancroft-Madoc area are mainly part of the Hermon and Mayo Groups; thick carbonate sequences occur in the latter. The youngest rock units represent part of the Flinton Group defined by Moore and Thompson (1980) in the Kaladar and adjacent areas, and are interpreted to unconformably overlie the volcanics, and carbonate and clastic rocks of the older groups of the Grenville Supergroup. The rocks of the Madoc Syncline may be correlative with the Flinton Group (Moore and Thompson 1980) in which the dominant lithologies include conglomerate, slate, dolomitic and calcitic marble, and calcareous and non-calcareous clastic metasediments. In the main study area from Havelock to Madoc and north towards Bancroft, the rocks have undergone greenschist facies regional metamorphism. Primary lithological features are commonly very well preserved.

Metasediments

Metasediments that underlie much of the area can be lithologically divided into three major groupings:

1. carbonate metasediments
2. calcitic metasandstone and metasiltstone
3. siliceous fine- to coarse-grained metasediments

Carbonate metasediments are the most extensive units and form most of Lumbers' Dunganon Formation (Lumbers 1969). These metasediments are further subdivided into calcite and dolomitic marble.

The calcitic marbles are mainly light to dark grey, fine to medium grained, and contain tremolite, phlogophite, minor pyrite, and in places, detrital quartz and feldspar. The units are generally finely laminated and thinly bedded. Locally medium- to coarse-grained calcite patches are abundant, and oriented at an angle to bedding.

These marble units are generally interbedded with calcitic siltstones and mudstones, but locally there are interbeds rich in silicate minerals, particularly near metavolcanics and near the major siliciclastic units, where a facies transition is present between the clastic siliceous and carbonate metasediments.

Dolomitic marbles are extensive in Belmont, Marmora, and Madoc Townships, and were also observed in Cardiff, Faraday, Gullford, Hatburn, Stanhope, and parts of Minden Township. The dolostones in the study area are mainly buff coloured and range from fine grained to medium grained, with locally well defined bedding. Tremolite, talc, micas, quartz, and pyrite are present. Some of the dolomitic units in the area are associated with laminated quartzose structures (stromatolites) inferred to be biogenic in origin.

In Belmont and Madoc Townships, the dolostones also show extremely well preserved stylofibrous cement, which formed as cavity fills between and under thin algal mats. Geopetal structures and different generations of cement were noted. The formation of this stylofibrous cement is inferred to be submarine in origin (Kerans and Donaldson 1979). Within the Grenville Province, this unique style of cementation has so far been found only in localities in Belmont and Madoc Townships.

The dolomitic units are extensive and can be used as marker horizons. Local discontinuities may be attributed to either structural attenuation, erosion, or to non-deposition. Terrigeneous impurities vary with location. In the reconnaissance area, west from Burleigh Falls to Haliburton, dolomite is coarse grained, recrystallized, and in most places, pure white as a result of higher grade metamorphism.

In facies transitions between the carbonate rocks and clastic silicious rocks, calcitic sandstone, siltstone, and mudstone are interbedded with the carbonate rocks. These calcitic rock units range in colour from reddish to grey-green to brown and have varied amount of carbonate and/or siliceous matrix. Both calcitic and siliceous sandstones in places show low angle crossbedding and graded beds. In Marmora Township, alternate deposition of sand and mud produced penecontemporaneous deformation features that are well preserved at numerous localities.

Feldspathic sandstones locally are poorly sorted, fine grained, and show rhythmic bedding with repetitive sections, suggesting a turbidite origin. Subdivisions C and E of the Bouma Sequence are missing. These rocks may be classified as feldspathic wacke. In areas of higher metamorphic grade these wackes become amphibole rich.

Some of the sandstone units are poorly sorted, possibly implying a nearby source, but other units are clean and well sorted, probably from a more distal source and longer transport which would account for the more rounded fragments. It has been suggested by Lumbers (1967) and others that volcanic activity and marine sedimentation were taking place simultaneously, and that the poorly sorted feldspathic sandstone units were eroded from nearby volcanic rocks. The common association of carbonate rocks with meta-tuffs and siliceous metasediments rich in volcanic fragments, indicate volcanic and tectonic activity in or adjacent to the basin of deposition.

Coarse clastic sediments are found at several localities. In the Belmont Lake area, a thick sequence of mainly conglomerate is present; ortho- and paraconglomerates make up a substantial portion of the overall thickness, but sandstones and siltstones also occur. Red bed sequences show paleochannels and evidence of emergence. Paraconglomerate units are extensive, have nonerosional bases and lack stratification. The orthoconglomerate units are extensive and may exhibit large and small scale crossbedding, reactivation surfaces, and erosional scours, and may be stream channel deposits.

The coarse clastic metasediments periodically give way to dolomitic units with domal and laminar algal mats,

and dolomitic conglomerates. The dolomite clasts in these conglomerates commonly have a stylofibrous cement.

Organosedimentary Structures

Fine-grained quartzose dolomitic marbles of greenschist to lower amphibolite facies show well preserved laminated structures, which the author considers to be biogenic in origin and can, therefore, be classified as stromatolites. Columnar and domal stromatolites are found at Belmont Lake, Marble Lake, L'Amable, and in the Madoc Syncline. Despite deformation and recrystallization, millimetre scale laminations are present in essentially pure dolomite. The lenticular silicified finely laminated structures at Belmont Lake and near Madoc were formerly described as *Eozoon canadense* (Wilson 1957).

The structures in the detailed study area and in the reconnaissance area vary from crenulated tabular structures to irregular domal and columnar shapes. A unique form of domal stromatolite was found in a dolomite unit of the Flinton Group in the Madoc Syncline. In cross-section, these domal forms show a sharp apical angle with a defined central axial column. Several of these domal forms show branching. These domal stromatolites are very much comparable to the Conophyton group described elsewhere from the Precambrian.

These structures are interpreted as relict patches of silicified and recrystallized algal colonies. The identification of these structures as algal mats suggests a shallow subtidal to intertidal origin for the enclosing carbonate metasediments, and thus represents a major advance in the interpretation of sedimentary environments in the Grenville Supergroup that may be applicable on a regional basis (Bourque *et al.* 1982).

Economic Significance

It has been well demonstrated around the world that many stratiform mineral deposits are associated with "ocean-edge environments" where the potential ore-forming elements could be supplied to the sedimentary basin in a variety of ways (Mendelson 1976). Depending on the conditions of sedimentation these elements may be dispersed or concentrated. Orebodies may or may not be associated with stromatolites, and are often found within or adjacent to dolomites and associated shales, siltstones, or tuffaceous units (Gauthier and Brown 1980).

The Grenville Supergroup marbles and associated metasediments host numerous occurrences of stratiform mineralization, among which are Long Lake and Renfrew in Ontario, Calumet Quebec (Quebec), and Balmat-Edwards in New York State. It has been noted at these locations that mineralization is associated with dolomitic carbonate rocks and with the transition zone between dolomitic and other metasedimentary units. The quartzose laminated structures described previously in the dolostones can be traced from well preserved sites to highly deformed areas, and can be used as very good stratigraphic markers. The paleoenvironmental and stratigraphic results of the present study, therefore, may eventually help to trace and define horizons of economic mineralization.

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No. S10 Geology of the Queensborough Road Talc Occurrence

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Introduction

The objective of this project is to examine in some detail, the geology and setting of a large talc-bearing zone located in southwestern Elzevir Township, centred approximately at Latitude 44°35'N and Longitude 77°22'W. Access to the area is excellent because the talc zone is crossed by several gravel and paved roads some 3 to 5 km north of Highway 7, just west of the Village of Actinolite.

This talc occurrence, known since before the turn of the century, received some attention in the 1940s, but has since that time remained largely unexplored. Recent interest by several companies in developing large tonnage lower grade talc properties in response to the recently improved and expanded market for talc fillers, has resulted this year in active exploration of 2 properties located on the Queensborough Road talc-bearing zone.

Mineral Exploration

The area was first prospected for talc and actinolite in the late 1800s when the Henderson Talc Mine (now Canada Talc Industries Limited) in nearby Huntington Township, and the actinolite deposits in Elzevir Township, were discovered. Several test pits of modest dimensions were sunk within the present map-area, but no production of talc resulted, owing to the inability of the operators to economically mill and beneficiate this ore. Reports by Spence (1922, 1940), Wilson (1926), Thompson (1943), and by Hewitt (1972) describe in varying detail the early history, development, and geology of talc properties in the area. Lumbers (1968) describes the geology of a similar mafic to ultramafic-hosted talc showing in Cashel Township, some 50 km to the northwest of the Queensborough Road Occurrence.

In 1981, strong interest revived in the developed possibilities of lower grade talc occurrences in southeastern Ontario. In 1982, 2 companies, Steep Rock Iron Mines Limited, and Canada Talc Industries Limited (recently purchased by William R. Barnes Company Limited) both commenced detailed field evaluations of their properties on the Queensborough Road Talc Occurrence. Activity to date has included mapping, sampling, diamond drilling, and limited bench-scale testing of talc zones on both properties.

Field studies by the Ontario Ministry of Natural Resources on talc occurrences in southeastern Ontario were initiated in 1979, and a preliminary unpublished summary report by van Haaften, Young, and Kingston (1980) was completed. More detailed follow-up mapping of selected occurrences followed in 1981, and because very little field data was available on the numerous talc occurrences of mafic to ultramafic affiliation in Elzevir, Grimsthorpe, and Cashel Townships, this Queensborough Road zone was chosen for detailed mapping at a scale of approximately 1 inch to 200 feet. Mapping was carried out during the 1982 field season by Owen J. Steele and the author. Subsequent chemical, analytical,

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

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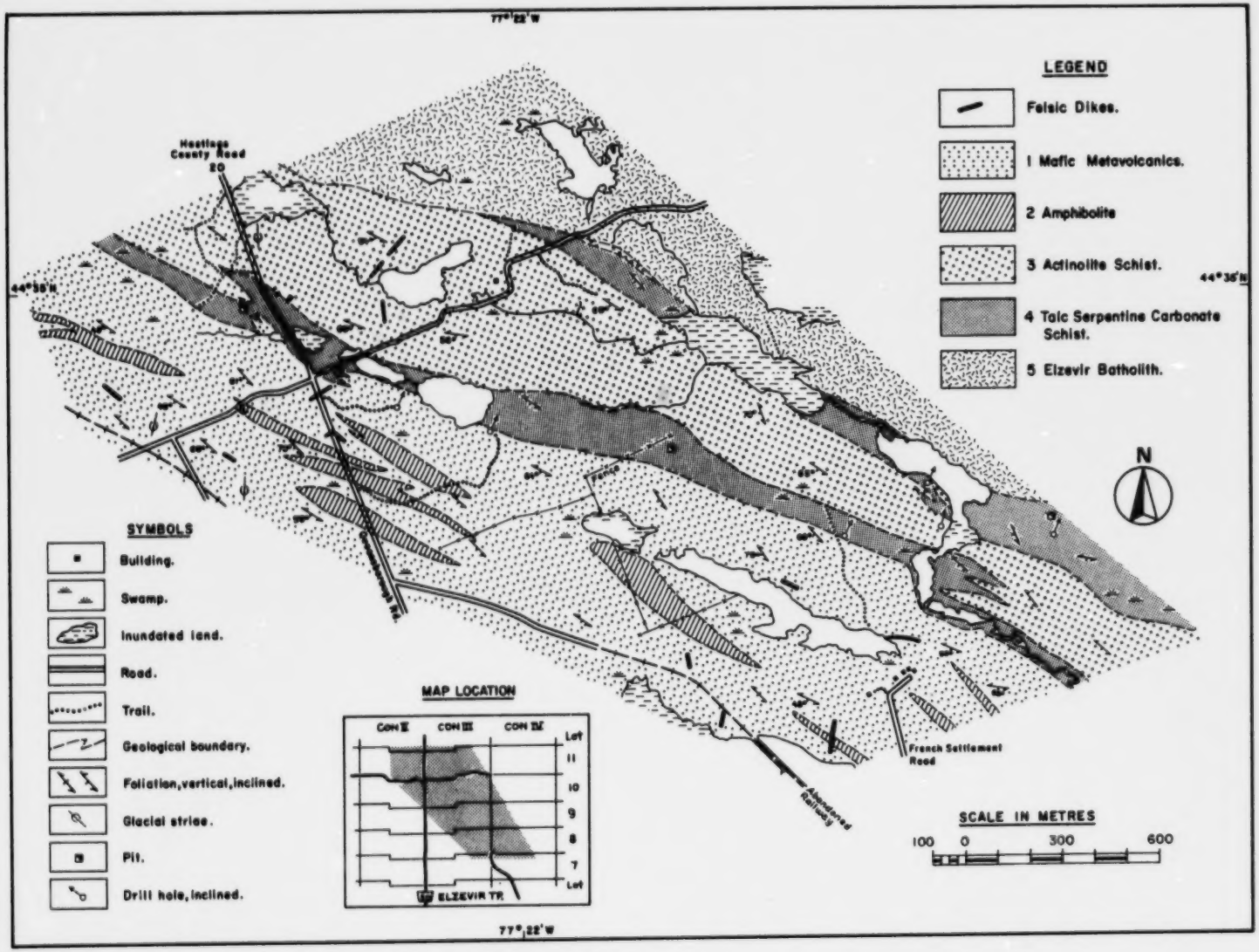

Figure 1—Generalized geology of the Queensborough Road Talc Occurrence.

and petrographic studies are intended to elucidate the origin of this deposit, and will contribute to our knowledge and understanding of this poorly documented type of talc occurrence in southeastern Ontario. Such information should provide effective prospecting and exploration guides to these mafic- and ultramafic-hosted deposits.

General Geology

Introduction

The present map-area is located in the Central Metasedimentary Belt of the Grenville Province in southeastern Ontario, as defined by Wynne-Edwards (1972). Rocks in the area belong to the Grenville Supergroup, and include mafic to felsic metavolcanics and associated metasediments of the Hermon Group. Outside the map-area the Hermon Group is overlain by a sequence of clastic and carbonate rocks of the Mayo Group, which enclose the carbonate-hosted talc deposits near Madoc. Structurally, the map-area lies in the Hastings Basin as defined by Wynne-Edwards (1972). Biotite-diorite and syenite-monzonite intrusions (Lumbers 1980) intrude Hermon Group rocks in the immediate vicinity of the map-area. Thermal metamorphic aureoles surround these intrusions in this area of regional greenschist facies metamorphism. The map-area lies wholly within such a thermal aureole according to Lumbers (1964), and in this area the grade of metamorphism is raised to amphibolite facies.

Structurally the region is very complex, resulting from repeated intense folding and deformation associated with several periods of tectonism, the most pervasive of which is known as the Grenvillian Orogeny. Major faults have a general northwesterly trend, and show only limited displacements where field data are available.

Description of Map Units

Within the map-area (Figure 1), the older mafic metavolcanics of the Tudor Formation are intruded by a trondhjemite-granodiorite pluton, the Elzevir Batholith.

The regional strike within the study area is southeasterly, and dips are generally to the southwest.

Mapping by the author has delineated 5 distinct rock units:

Unit 1: Mafic Metavolcanics

Unit 2: Amphibolite

Unit 3: Actinolite Schist

Unit 4: Talc-Serpentine-Carbonate Schist

Unit 5: Elzevir Batholith

Map Unit 1: Mafic Metavolcanics

The mafic metavolcanics which outcrop in the western part of the map-area, constitute approximately one-third of the bedrock in the study area. They consist of fine- to medium-grained rocks ranging from basalt to andesite in composition. The fine-grained rocks are generally moderately to highly foliated, while the medium-grained variety possesses only a weak foliation. Locally these rocks are hydrothermally altered to a micaceous chlorite schist.

Within the mafic metavolcanic unit there are minor beds of siliceous metatuff. They rarely exceed 15 m in thickness and are discontinuous along strike.

Highly foliated rusty schists within Map Unit 1, occur in relatively small zones that conform to the regional strike within the area. Pyrite mineralization (up to 10 percent pyrite), occurs as thin stringers parallel to foliation.

Rusty schists are recognized throughout the region and are described by Lumbers (1968) in some detail. Base and precious metals commonly occur within these rocks, however few deposits have yet shown any economic potential. Massive pyrite lenses have been mined from rusty schist zones in the region for the production of sulfuric acid. Rusty schists are recognized within metavolcanics, and clastic and carbonate metasediments.

Map Unit 2: Amphibolite

The amphibolite possesses distinct physical characteristics, well defined contacts, and underlies sufficiently large areas to be mappable as a separate unit, even though it is similar in composition to the fine- and medium-grained mafic metavolcanics of Map Unit 1, and belongs to the same stratigraphic horizon.

This amphibolite is poorly foliated, dark green to black in colour, and is medium to coarse grained.

Map Unit 3: Actinolite Schist

Map Unit 3 represents a medium-sized homogeneous actinolite-plagioclase schist. It outcrops between the mafic metavolcanics (Map Unit 1) and the Elzevir Batholith (Map Unit 5), and lies in contact with the talc-serpentine-carbonate schist (Map Unit 4) on both the eastern and western boundaries (Figure 1). Segregated bands of an actinolite-plagioclase rock occur at or near the contact of the talc-serpentine-carbonate schist (Map Unit 4). Chlorite alteration is also apparent near the contact.

The actinolite schist (Map Unit 3) appears to be closely associated with the talc-serpentine alteration and probably represents the unaltered equivalent of the talc-serpentine-carbonate schist (Map Unit 4).

Map Unit 4: Talc-Serpentine-Carbonate Schist

The talc-serpentine-carbonate schist is observed only in 2 areas. One zone lies in contact with the mafic metavolcanics (Map Unit 1), and the actinolite schist (Map Unit 3), and is designated as the west zone (Figure 1). The east zone outcrops between the Elzevir Batholith (Map Unit 5), and the actinolite schist (Map Unit 3). Both zones are approximately 100 to 200 m wide, and appear to extend beyond the northern and southern boundaries of the map-area.

Map Unit 4 is comprised of serpentine-rich and talc-rich schists, both of which are composed of talc, serpentine, dolomite, and magnetite in varying proportions. The highest concentrations of magnetite correspond to dolomite-rich zones which contain little talc, and conversely, talc-rich zones contain less magnetite.

The serpentine-rich rock is the more common and constitutes the major part of Map Unit 4. Small lenses or veins up to 5 cm in width of nearly monomineralic plagioclase are recognized in the serpentine-rich zones.

The talc-rich schist is wholly enclosed within the serpentine-rich zones as relatively small lenticular bodies that tend to pinch out or grade into the enclosing serpentine-rich schist. The largest talc-rich zones are approximately 30 m wide and less than 100 m in length, and are visually estimated to be composed of 25 to 50 percent talc. Within these lenses, veins up to 15 cm wide are composed of almost pure talc.

Map Unit 4 is highly deformed, displaying several planar orientations, however, the dominant foliation conforms to the general structural trend.

Map Unit 5: Elzevir Batholith

The Elzevir Batholith outcrops in the eastern part of the map-area and is described by Lumbers (1964) as trondhjemite-granodiorite in composition, and by Wolff (1982) as chiefly biotite granodiorite to quartz monzonite in composition. Several small, fine-grained felsic dikes of similar composition intrude the surrounding rocks.

The thermal metamorphic effects of the felsic intrusion may have had a genetic relationship with the talc-serpentine alteration. No clear relationship between the degree of alteration and distance from the intrusive contact, however, can be observed.

Discussion

The origin of the talc mineralization is not clearly understood at the present time. Field evidence of consistent spatial proximity between Map Unit 4 (talc schist) and Map Unit 3 (actinolite schist) implies a genetic relationship between the two. Thus the origin of Map Unit 3 must be solved first. Examination of the field evidence suggests that Map Unit 3 may have originated in one of several ways. These are:

1. Map Unit 3 is a komatiitic flow.
2. Map Unit 3 is a mafic to ultramafic dike or sill.
3. Map Unit 3 is the product of assimilation between the Elzevir Batholith (Map Unit 5) and the mafic metavolcanics (Map Unit 1).

Whatever the origin of Map Unit 3, it seems evident that the talc-rich zones (Map Unit 4) were derived by alteration of parts of Map Unit 3. The talc zones are along the margins of Map Unit 3 possibly because these margins were more susceptible to alteration. This seems logical because if Map Unit 3 is a komatiitic flow, then the margins would represent the more porous flow-top breccias. If Map Unit 3 is a mafic to ultramafic dike or sill, then the margins would represent cooler contact zones susceptible to serpentinization, whereas the central part would preferentially alter to actinolite. Thirdly, if Map Unit 3 is the product of assimilation between the Elzevir Batholith (Map Unit 5) and the mafic metavolcanics (Map Unit 1), then upon cooling the margins of such a zone again would be more likely to undergo serpentinization from later hydrothermal solutions.

The possibility also exists that Map Unit 4 rocks represent individual flows or small sills that are komatiitic in composition or at least more magnesium-rich than Map Units 1 and 3.

Conclusions

1. Talc-serpentine-carbonate schists in the Queensborough Road area are of mafic or ultramafic affiliation, and are associated with mafic to ultramafic volcanism or intrusion.
2. Talc mineralization is confined to 2 northwest-trending zones composed of talc-serpentine-carbonate schists which conform to the regional structural trend. These zones are approximately 100 to 200 m wide and most probably extend beyond the northern and southern boundaries of the map-area.
3. Potentially economic talc mineralization is confined to small higher-grade lenses within these schists and are approximately 30 m wide and less than 100 m long. The visually estimated grade of the talc-rich lenses is from 25 to 50 percent talc. Thin veins of pure talc occur within these lenses.
4. Talc mineralization is associated with serpentine, dolomite, magnetite, and rarely plagioclase.
5. The contribution of the felsic intrusive rocks to the origin of the talc mineralization is not readily apparent.
6. The talc-serpentine-carbonate schist is genetically related to the actinolite schist.
7. Future prospecting for talc of mafic-ultramafic affiliation should be directed to the narrow zone immediately along the southwestern margin of the Elzevir Batholith. Outcrop of talc-serpentine-carbonate schist is reasonably plentiful, but care should be taken not to overlook low-lying and swampy topographic linears parallel or sub-parallel to the intrusive contact.

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Engineering and Terrain Geology Programs

Summary of Activities of the Engineering and Terrain Geology Section, 1982

Owen L. White[1]

Field parties were active throughout the Province; regional mapping projects were conducted in 10 areas, with aggregate assessment studies in 6 areas, and special topics in 3 additional areas. In the first phase of the investigation of oil shales in Ontario, drillholes were located at 22 sites, selected to ensure the collection of samples from the Ordovician Whitby and Billings Formations. Funding for more than half of the field projects was received from either other Ministries of the Ontario Government or the Federal Department of Regional Economic Expansion (DREE), or both.

P.J. Barnett commenced the mapping of the Quaternary geology of the Long Point-Port Burwell areas along the shoreline of Lake Erie and immediately south of the Simcoe and Tillsonburg areas, previously mapped by him. Sand deposits are extensive, but very little gravel occurs except in former glacial lake beach deposits. The lakeshore bluffs, actively eroding in many places, provide excellent exposures of the glacial stratigraphy and provide ample opportunity for detailed examination of the various sedimentary environments. Subsurface drilling to provide further stratigraphic information is planned for late 1982.

In eastern Ontario, James G. Leyland continued the mapping of the Sydenham, Bath, and Yorkshire Island areas, to complete the mapping of a block of map-areas along the northern shore of Lake Ontario. P.F. Finamore completed the mapping of the Bannockburn area, and made some detailed studies of the Dummer Moraine which appears to extend about 160 km across central and eastern Ontario. The Dummer Moraine also occurs in areas mapped by Leyland in 1982 and the 2 previous years.

The drift cover in the Sydenham and Bath areas is generally thin, except where it thickens in the drumlinized area to the west of the map-areas or in the Dummer Moraine to the north. The material in the Dummer Moraine is characterized by a high content of Paleozoic carbonate bedrock within a sandy matrix. This type of till-like sediment occurs along the entire length of the Dummer Moraine. Detailed studies by Finamore suggest that this characteristic "high carbonate till" has a complex relationship with the lodgement till (which contains not only fewer clasts in total, but a much higher percentage of Precambrian bedrock clasts) found in the drumlins and the till plain to the south. Finamore considers the 2 tills are facies of one another and were probably deposited by subglacial processes. Leyland holds to the opinion that the coarse material of the Dummer Moraine has been derived from englacial and supraglacial debris in the melting ice.

At the request of the Regional Parks Co-ordinator of the Ontario Ministry of Natural Resources, Algonquin Region Office at Huntsville, two field parties were placed in the northern portion of Algonquin Provincial Park. The purpose was to map and record the surficial geology, identify surficial geological features for the Park's interpretive program, and locate and describe useful deposits of sand and gravel for internal park construction. Both field party leaders (R.S. Geddes and M.J. Ford) reported similar geological conditions from their respective map-areas. The last advance of the Wisconsinan ice over the report areas was from the north and northeast, and remained fairly consistent over the whole area. Lodgement and ablation tills have been found across both areas but considerable quantities of drift were derived from the various processes associated with the melting of the glacier.

[1]Chief, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

Many of the outstanding physiographic features in the area are closely related to the established canoe routes in the park. Useful sand and gravel deposits occur right across both map-areas and provide useful sources for road construction and fill. In some areas, primary crushing will be necessary because of the high percentage of oversized material. Some deposits are fairly inaccessible at present and will require a more detailed evaluation before their usefulness can be determined.

P.F. Karrow mapped the Quaternary geology of St. Joseph Island, and reports a variety of landforms and materials. A sandy to gravelly till occurs throughout the island in the form of drumlins, end moraines, and a till plain. Lacustrine red and grey clays, sands, and gravels overlie much of this till surface below the highest level of glacial Lake Algonquin. Above 285 m above sea level, the original till surface is well exposed. Algonquin beach levels are well developed on the island, particularly around the highest portion of the island which remained above lake level. Large quantities of sand and gravel are found in these beaches, but are currently only used for local purposes.

In the Kirkland Lake area, C.L. Baker completed the field work started in 1978 with the mapping of 4 map-areas, followed by detailed studies on a number of eskers in the area. The objective of the later stages of the program is to show how the study of eskers can be used as a prospecting tool.

Exposures in 27 gravel pits were investigated in 1982, frequently with the aid of mechanical equipment to provide ready access to clean faces. Samples were taken and split into coarse and fine fractions. Pebble-sized material was identified visually, and the fine fraction (<230 mesh) was retained for geochemical analysis.

In 1981, a small piece of kimberlite was found in a pit in Gauthier Township. This year an additional piece weighing 11.6 kg was found. This find raises hopes that the source of the kimberlite might be found within a short distance of Kirkland Lake.

James A. Richard has completed the Quaternary geology mapping of 2 areas which lie largely within the boundaries of the City of Timmins. Most of the area is underlain by Matheson till to depths of up to 15 m. Superimposed on this till plain are 6 major esker systems, ranging in length up to 100 km. All areas below an elevation of 295 m are covered by lacustrine clays and silts deposited in glacial Lake Barlow-Ojibway. These lacustrine sediments are up to 35 m thick, especially in the Pamour map-area. In the northern portions of the map-areas, silty clay till of the Cochrane readvance is found.

The various esker systems in the area contain considerable resources of sand and gravel. The Murphy esker, along Highway 655, presently supplies most local requirements, but other resources should become available as the Murphy esker is depleted. The thick deposits of lacustrine clays are the source of some slope stability problems along river banks and lake shorelines.

D.A. Williams and Rainer R. Wolf have completed the mapping of the Paleozoic rocks of eastern Ontario which was started last year by D.M. Carson. Bedrock exposures were common on the western side of the map-area and along the length of the Ottawa River. Elsewhere, the glacial drift deposits were too thick to allow many exposures. Observations were improved through the inspection of the excavations for the Trans-Canada pipeline which ran through several map-areas.

Sandstones of the Covey Hill Formation and the Nepean Formation underlie a sequence of Ordovician dolostones, sandstones, shales, and limestones. The Middle Ordovician Ottawa Formation is said to be divisible into 6 mappable lithostratigraphic units, and more detailed studies are suggested. The Upper Ordovician Carlsbad and Russell Formations are considered lithologically indistinguishable in the field and the proposal is made to group them together

Many faults and fault zones occur within the map-area, and many have been exposed for the first time in recent years. The author proposes to present a major revision of previous published work on the structural geology of the area.

The March, Oxford, and Ottawa Formations are all used for the production of crushed stone, and the Queenston Formation is used for the production of bricks. The Nepean Formation is considered to be a potential source of silica for the glass and foundry industry.

The investigation this year of Paleozoic(?) rocks in the Sault Ste. Marie area by D.J. Russell was enhanced by a major excavation into the Jacobsville Sandstone for the reconstruction of the hydro-electric power plant of Great Lakes Power Limited. The opportunity was taken to record as much information from the excavation as the available time permitted. Later, the field work was extended to an investigation and mapping of the Paleozoic rocks both on the mainland and on St. Joseph Island. Relevant outcrops in Michigan were also visited during the course of the field activities. Nevertheless, the age of the rocks of the Jacobsville Formation remains unresolved. Elsewhere, and especially on St. Joseph Island, the rocks younger than the Jacobsville Formation are considered to be of Upper Cambrian (Munising Formation) and Middle Ordovician (Gull River and Shadow Lake Formations) age.

The staff of the Aggregate Assessment Office were active in 6 areas in southern Ontario during the 1982 field season in order to collect data for several inventory projects under way at the present time. In several areas where little pre-existing data was available, drilling and geophysical investigations were undertaken to provide a minimum of information with which to prepare the inventories. In the Fonthill area, a number of holes were drilled to provide information on the long-term potential of the regionally important sand and gravel deposit in that area.

In Southwest Oxford Township, Oxford County, staff geologist P.J. Barnett, and V.H. Singhroy of the Ontario Centre for Remote Sensing, were involved in a special field project to evaluate remote sensing techniques for locating buried deposits of sand and gravel. Surface field parties were involved in collecting field data at the same time as an aerial crew was acquiring reflected and thermal infrared data over the same area. The results were sufficiently encouraging as to favour further studies in early 1983.

D.J. Russell and Owen L. White, assisted by J. Graham, continued their investigation of the geological effects of the presence of high horizontal stresses in near surface bedrock in southern Ontario. Newly reported structures were investigated and several of the more prominent structures were surveyed in detail. The measurement of stresses in the floor of a quarry near Ottawa is planned for late 1982.

Field studies as part of the Hydrocarbon Energy Resources Program (HERP) funded by the Board of Industrial Leadership and Development (BILD) were initiated during the first half of 1982.

M.D. Johnson reports the commencement of the subsurface investigation of the Ordovician oil shales of the Whitby Formation in southern Ontario, with the drilling and sampling of some 20 drillholes. Additional drilling and sampling of the stratigraphically equivalent Billings Formation in eastern Ontario was also carried out. Samples from all drillholes have been analyzed at the University of Waterloo and results are expected to be released shortly as an Open File Report. Further drilling will be done in late 1982 to investigate the subsurface character and distribution of the Devonian shales of the Marcellus and Kettle Point Formations in southwestern Ontario.

As a prelude to an extensive, multi-year investigation of peatlands in Ontario, W. Shotyk and P.G. Telford report on a comparative study of peat deposits in 3 areas in northern Ontario.

A deposit in Galbraith Township northeast of Bruce Mines, in which previous investigations had been undertaken, was the first area sampled. This deposit is located on bedrock of the Gowganda Formation with copper mineralization common throughout the area. The surrounding terrain varied from a ground moraine cover to bare rock outcrops.

The deposit investigated in the Timmins area is located on bedrock with widespread sulphide mineralization and numerous diabase dikes. Surficial deposits ranged from la-

custrine clays and silts to a clayey till ground moraine. Ground checks in this area supplemented remote sensing of the area by staff of the Ontario Centre for Remote Sensing, Ontario Ministry of Natural Resources, Toronto.

The third area of study was along a line running from Timmins to Moosonee. Several peat deposits were sampled along the transect which cut across several types of geologic conditions.

A wide variety of peat types was sampled, and samples have been submitted to the Geoscience Laboratories, Ontario Geological Survey, Toronto, together with samples of the mineral sub-layer, for trace element analysis. The results of the sampling and the analyses will be issued in an Open File Report format in early 1983.

No. 15 Quaternary Geology of the Long Point-Port Burwell Area, Elgin County and the Regional Municipality of Haldimand-Norfolk

P.J. Barnett[1]

Introduction

The Quaternary geology of the Long Point-Port Burwell area (Long Point NTS 40 I/9, and Port Burwell, NTS 40 I/10, scale 1:50 000) was mapped during the summer of 1982. This area is located along the north shore of Lake Erie, and is bounded by Latitude 42°45'N and Longitudes 80°00'W and 81°00'W.

The communities of Port Burwell, Straffordville, Langton, Port Rowan, Long Point, St. Williams, and Turkey Point occur within the area mapped. Farming is the principal economic activity of the area and is dominated by tobacco and rye in the sandy areas, and corn, soya beans, cucumbers, tomatoes, and peppers on the finer textured soils.

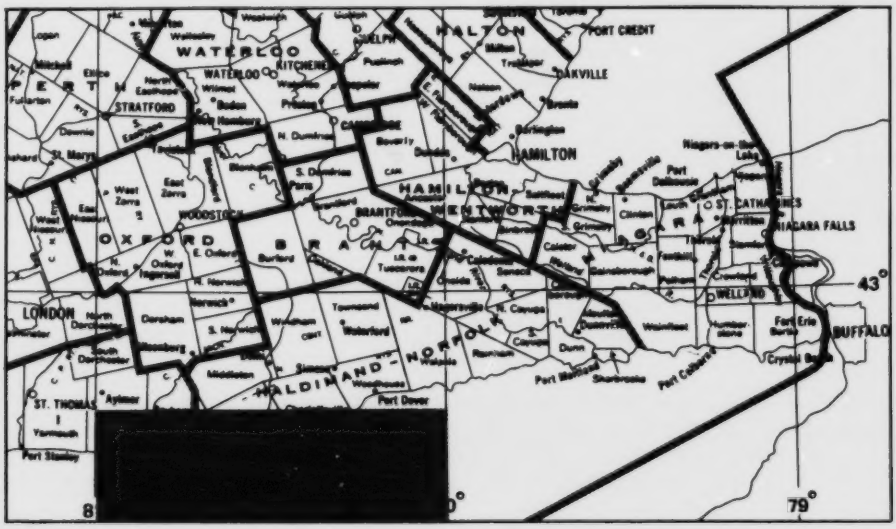
Local geological concerns include the loss of land to erosion along Lake Erie, gullying and failure along deeply incised creeks, loss of topsoil through wind erosion, lack of local aggregate sources, drainage in finer textured soils, and sources of water for irrigation.

[1]Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

Physiography

The area occurs within the physiographic regions of the Norfolk Sand Plain and Erie spits (Chapman and Putnam 1966). The Erie spits physiographic region includes the three large sand spits of Lake Erie. The longest of three spits, Long Point, extends some 41 km into the lake and is completely within the map-area.

The remainder of the map-area is in the Norfolk Sand Plain physiographic region: a region characterized by a gently sloping sand plain with minor relief provided by eolian dunes of up to 10 m. The region is deeply dissected (up to 50 m) along the rivers and creeks which drain the area, and along the Lake Erie shore. Local relief of 55 m exists at the Sand Hills, a large cliff-top dune.



LOCATION MAP **Scale: 1:1 584 000 or 1 inch to 25 miles**

General Geology

No bedrock is exposed at the surface in the map-area. The cover of Quaternary sediments over the bedrock ranges from 30 m up to 100 m. Drift thickness and bedrock topography for parts of the area have been published previously by Sibul in 1969, and Yakutchik and Lammers in 1970. Maps providing this information over the entire map-area will be published by the author, early in 1983.

Quaternary deposits observed this past summer are of Late Wisconsinan age. Older drift probably exists at depth but was not encountered during this study.

The Port Stanley Drift (de Vries and Dreimanis 1960) was the oldest sediment observed, being deposited during the Port Bruce Stadial. It is composed of several layers of Port Stanley Till, a clayey silt to silty clay with a low clast content (<1 percent), numerous glacially derived sediment flows (waterlain tills and flow tills), and glaciolacustrine sediments ranging from cyclically bedded (varved?) sands and clay to well interlaminated clay and silt (varves).

Three distinct glacial advances are recorded within the Port Stanley Drift in exposures along the Lake Erie shore-bluffs. Ice-marginal positions are marked by the southern limb of the Tillsonburg Moraine, the Courtland Moraine, the Mabee Moraine, and an area of till outcrops east of Lakeview.

The Wentworth Till (Karrow 1963) is exposed at the surface, in places, in the eastern half of the map-area. In the north, this till is typically sandy silt- to silt-textured, with a stone content of 5 to 10 percent; in the south near its outer margin it has a clayey silt matrix as a result of the glacier incorporating fine-textured glaciolacustrine sediments into its base. Glaciolacustrine sediments and glacially derived sediment flows are also associated with the Wentworth Till.

Glaciolacustrine sediments cover the majority of the map-area. Sands of the Norfolk Sand Plain are the predominant surficial sediments, with deeper water silts and clays outcropping along several of the larger creek valleys, and along the Lake Erie shore west of Port Burwell, around Port Rowan, and east of Fishers Glen.

Abandoned shoreline features of Glacial Lakes Whittlesey and Warren, as well as some of the younger lakes, are present but are not very distinct.

Several sites containing organic material were found in the map-area. Organic material was found beneath Wentworth Till, in upper glaciolacustrine sediments, in an abandoned fluvial terrace, and beneath eolian sand. Further studies on these sites will provide information and a timetable for the deglaciation and post-glacial events of the Long Point-Port Burwell area.

Economic Geology

Sand and gravel have been extracted from a few small pits in beach sediments along the Tillsonburg Moraine northwest of Mount Salem. These pits were inactive during the summer of 1982 and some already have been rehabilitated. Winter sand was extracted from lot 19, concession II, Charlotteville Township, this past winter and will be in operation next season (Joe Strachan, Ontario Ministry of Natural Resources, Simcoe District, personal communication, 1982). This pit is in a deposit which is buried by glaciolacustrine sands and silts, probably an extension of the "Simcoe delta" (Barnett 1978). Sand was also being extracted for fill from several dunes in the area.

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No. 16 The Evaluation of Remote Sensing Techniques for Locating Surface and Near-Surface Mineral Aggregate, Southwest Oxford Township

P.J. Barnett[1] and V.H. Singhroy[2]

Introduction

The mapping of surface materials, including mineral aggregate, is done primarily by integrating field observations with the extensive use of air photographs. This involves the identification and classification of surficial materials and their landforms from which material variability, quality, and potential uses are obtained.

In the search for subsurface mineral aggregate, however, no single technique is adequate. A combination of glacial stratigraphy, sedimentology, geophysical studies, and drilling is commonly used by the Engineering and Terrain Geology Section.

The purpose of this project is to investigate the contribution of airborne infrared remotely sensed data in the delineation of surface mineral aggregate deposits, and in the detection of surface features and conditions indicative of subsurface mineral aggregate. Emphasis is placed on the distribution of soil moisture and the detection of micro drainage as indicators of the texture of the surficial material and of the subsurface material type. Reflective and thermal infrared imagery highlights moisture conditions, thereby aiding the mapping process.

This project is a joint study of the Ontario Geological Survey and the Ontario Centre for Remote Sensing.

Project Background

A small part of Southwest Oxford Township is being investigated in order to gain a better understanding of the origin and extent of several buried aggregate occurrences which were previously reported by Cowan (1975).

[1]Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

[2]Geologist, Ontario Centre for Remote Sensing, Ontario Ministry of Natural Resources, Toronto.

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

TABLE 1 SUMMARY OF MOISTURE CONTENT OF SURFICIAL MATERIALS

MATERIAL TYPE	AVERAGE MOISTURE CONTENT PER PROFILE	NUMBER OF PROFILES/ NUMBER OF SAMPLES
Glaciofluvial outwash sand underlain by gravel	17	1/6
Thin sandy silt till (Tavistock Till) over gravel and sand	20	6/40
Glaciofluvial outwash sand	22	1/6
Sandy silt till (Tavistock Till), no near-surface gravel and sand	27	1/4
Clayey silt till (Port Stanley Till)	28	1/6

The project commenced in August of 1981, when several sand and gravel pits and road cuts were examined and a drilling program was undertaken in association with the Aggregate Assessment Office, Ontario Geological Survey, Toronto.

In the spring of 1982 simultaneous coverage of 1:15 000 scale infrared (0.7 to 0.9 μm) and 1:20 000 scale thermal infrared (8 to 14 μm) was flown by the Ontario Centre for Remote Sensing. At the same time a total of 80 samples were collected from the different surficial materials throughout the study area. These samples were subsequently analyzed for their soil moisture content by the Geoscience Laboratories, Ontario Geological Survey, Toronto.

A Barnes PRT 10 hand-held infrared radiometer was used to measure the apparent surface temperatures of the natural surfaces when the remote sensing data was being flown. The readings were used to calibrate the temperatures recorded on the thermal infrared imagery.

Geological Background

The area investigated is located in an interlobate zone which was influenced by two lobes of glacial ice; one in the Huron-Georgian Bay basin (Tavistock Till) which flowed south-southeasterly and one in the Lake Erie basin (Port Stanley Till) which flowed towards the northwest during the Port Bruce Stadial, about 15 000 to 13 500 years ago.

The aggregate deposit of interest was deposited in a river which flowed south-southwestward, possibly between these two ice margins, or in an early interlobate zone during the Nissouri Stadial (Catfish Creek Drift).

The aggregate deposit was then overridden by an advance of the Huron-Georgian Bay lobe and its surface was drumlinized and covered by the Tavistock Till (sandy silt till).

During deglaciation, erosion of the area occurred exposing the aggregate deposit only along the slopes of younger melt-water channels. It is along these slopes that many of the sand and gravel pits exist.

Aggregate Deposits

A large portion of the Tavistock Till plain within the study area has sand and gravel beneath it. Thicknesses of sand and gravel up to 80 feet have been extracted in the past (Cowan 1975).

The material in the pits immediately south of Woodstock consists predominantly of thick sequences of imbricated, planar-bedded coarse gravels and trough crossbedded gravels and sands indicative of proximal outwash. The material in the deposit becomes finer textured southward where trough and planar crossbedded gravel, gravelly sands, and sands are predominant (more distal braided stream facies).

Chert is present in the pebble grade between 7 and 15 percent and is considered deleterious, however, it can be removed through heavy media separation.

Preliminary Analysis of Remote Sensing Data

Preliminary analysis of the remote sensing data and the results from the moisture content determinations revealed the following:

1. Thermal infrared (TIR) imagery can aid in the delineation of surficial materials. In several cases, TIR enhanced the contrast of tones resulting from different surficial materials and a refinement of boundaries was possible. TIR may be useful in very detailed mapping projects.
2. Areas with near-surface sand and gravel beneath the Tavistock Till contain characteristic "box gullies" that are readily recognized on the TIR as light-toned linear depressions, as they are well drained and significantly warmer.
3. The entire Tavistock Till surface in the study area is drumlinized and fluted. However, linear tonal variations on the TIR mosaic reflect the well developed drumlins and flutings only in the north and northwest. This corresponds to the thicker portions of the Tavistock Till where there are no near-surface aggregates. In areas

where sand and gravel is near to the surface the linear pattern is absent. These surficial expressions of characteristic tones and linear patterns give rise to two significant observations: (1) where the till is thick, a combination of moisture, landforms, and the till texture produce the characteristic tone and pattern; and (2) where the till is thin and well drained, the underlying sand and gravel produces a uniform light tone, thereby masking the linear pattern of the till surface.

4. The colour infrared imagery provides a clear discrimination between the two major till units. The predominantly clayey silt Port Stanley Till exhibits a characteristic and complex micro-dendritic drainage pattern, while the sandy silt Tavistock Till exhibits a uniform smooth texture and a lighter tone.
5. The moisture content of the surficial material sampled is a function of the material's grain size and is reflected by the infrared data. Moisture content increases from the coarser textured glaciofluvial outwash gravels and sands through the sandy silt Tavistock Till to the clayey silt Port Stanley Till (Table 1). This is exemplified again from tonal variations on both the reflected and thermal infrared imagery.
6. The moisture content of Tavistock Till samples underlain by sand and gravel is significantly lower than the moisture content of Tavistock Till samples taken where there are no near-surface aggregates (Table 1). This difference in moisture content within the same till is shown by subtle differences in textures and grey tones on the thermal infrared data.

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No. 17 Quaternary Geology of the Northeastern Part of Algonquin Park

M.J. Ford[1]

Introduction

The present study is part of a multi-year program of surficial geological mapping within Algonquin Park. The program was initiated at the request of the Regional Parks Co-ordinator, Algonquin Region Office, Ontario Ministry of Natural Resources, Huntsville, and is partly supported by Regional funding. Emphasis was placed on determining the Quaternary history, sediments, and landforms which could be used in the park's interpretive program, along with locating potential aggregate sources within the park for local forestry road maintenance and construction.

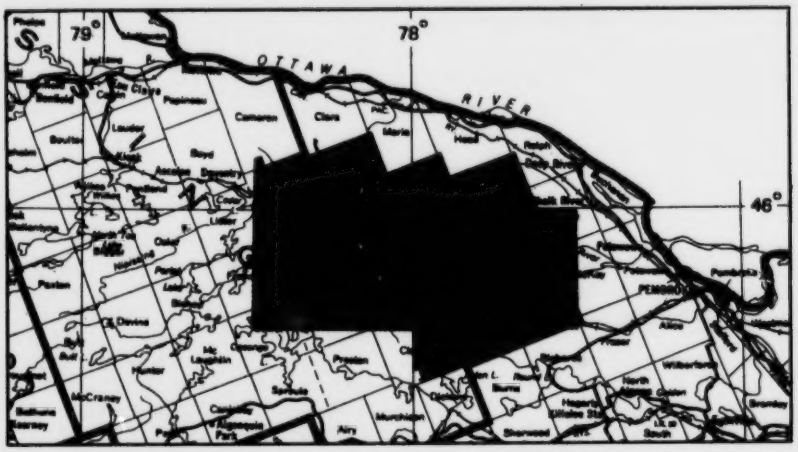
The study area includes the Achray (31 F/13) and Lac Lavieille (31 E/16) map-areas, and parts of the Round Lake (31 F/12), Rolphton (31 K/4), and Brent (31 L/1) map-areas. The area is approximately bounded by Longitudes 77°30'W and 78°30'W, and Latitudes 45°35'N and 46°10'N. The area was part of the regional physiographic study by Chapman (1975). Adjacent areas have been mapped by Gadd (1963) and Barnett (1979, 1980). Reconnaissance mapping of the Achray map-area was carried out during the previous field season by Kodybka (1981). During 1982, R.S. Geddes mapped adjoining park areas to the west. Geddes' work is summarized separately in this volume. Access to most of the area was provided by forestry roads supplemented by canoe traverses on some of the major lakes.

[1]Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

Bedrock Geology

The study area lies entirely within the Central Gneiss Belt of the Grenville Structural Province of the Canadian Shield. Except for limited occurrences of Ordovician carbonates, the rocks in the area are of Middle to Late Precambrian age. The northern and eastern parts of the area have been mapped at a 1:63 360 scale by Lumbers (1976a, 1976b, 1980). No published geological maps are available for the Lake Lavieille map-area. Overall metamorphic grade is middle to upper almandine amphibolite facies.

The northwestern part of the area contains biotite and migmatitic biotite gneisses derived from impure sandstones, garnetiferous metapelites, and minor calc-silicate gneisses and arkose-derived feldspathic gneisses. These metasediments are generally of Middle Precambrian age and are tightly to isoclinally folded with moderate plunge to the southeast. Similar meta-



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

sedimentary gneisses appear to be the main rock types of the southwestern part of the area. Gneissic monzonites and quartz monzonites intrude the clastic metasediments and become more prevalent eastward.

The eastern part of the area is dominated by the polyphase Algonquin Batholith. The batholithic rocks are principally biotite or amphibole-bearing quartz monzonites with minor syenite, quartz syenite, and monzonite, as well as anorthosites and related mafic rocks. These rocks are usually highly strained augen gneisses and rarely show primary mineralogy or igneous textures.

In the extreme northwestern corner of the area lies the Brent Crater, a circular depression of possible impact origin. It is approximately 3 km in diameter and contains up to 245 m of flat lying Middle Ordovician limestone over allochthonous breccias (Dence 1968; Currie 1971). There is at least one small outlier of Ordovician limestone near the hamlet of Brent on Cedar Lake.

A number of major faults associated with the Ottawa-Bonnechere system strike east-southeasterly across the area. There are numerous short, northerly striking lineaments between the major faults.

Physiography

To a great extent, the physiography is controlled by the bedrock faults. The courses of large streams, such as the Petawawa, Barron, and Bonnechere Rivers, are oriented along major faults, and many smaller streams run along the north-striking lineaments (faults?). On the up-thrown sides of major faults local relief may reach 160 m, with low relief and relatively thick drift on the opposite sides. The narrow up-faulted block bounded on the north by Grand Lake and on the south by Greenleaf, Carcajou, and Wenda Lakes forms a prominent highland trending east-southeasterly across the centre of the Achray map-area. South of this block the topography is generally subdued though punctuated by rock-controlled hills. The Bonnechere River is bounded on the south by a prominent fault scarp.

The influence of faults on the physiography is less pronounced in the western part of the area but bedrock control is apparent over much of the area. Relief is variable and locally, in highland areas, may exceed 100 m. Most of the numerous small lakes in the area are structurally controlled. Around Lake Traverse there is a major sand plain, the level topography of which is broken only by sparse rock knobs, kames, and sand ridges (dunes?). Several large eskers trend south-southwesterly across the area and are confined mainly to lowlands. A group of well formed drumlins with northerly orientations is located near North Rouge Lake.

Quaternary Geology

The ice-flow direction during the Late Wisconsinan varied across the area from 170° azimuth in the east to 210° azimuth in the west. Intersecting striae provide some evidence of a late westward re-advance in the Bissett Lake area.

The oldest and most widespread Quaternary deposit is a sand to silty sand till. The matrix is massive to distinctly fissile and often very compact but only weakly cohesive. Clast content averages about 5 percent. Locally the till exhibits weak stratification with moderate variation in texture and structure; sand stringers and lenses are often present. The colour of the unweathered till is medium grey to olive grey and maximum exposed thickness is 3 m. A loose till with 20 to 50 percent boulder and cobble clasts is also present and often overlies the more compact till facies.

Glaciofluvial deposits include outwash, eskers, and kames. As with modern streams, paleodrainage was largely controlled by the major faults in the eastern part of the area. Deposits of meltwater streams in the west trend south to southwest. Outwash deposits are present in low lying areas and consist of horizontally stratified sand, gravelly sand, and massive pebble to boulder gravel. Many display ripple cross laminations, and planar and trough crossbedding. In the Achray area sandy glaciofluvial deposits are typically capped by up to 1.5 m of poorly to moderately sorted massive gravel. This coarse upper facies may have been deposited during the Fossmill outlet stage of Great Lakes drainage (Chapman 1975). The extensive, terraced Lake Traverse plain is mainly outwash sand with minor ice-contact deposits of variable composition. There are a number of sharp-crested, asymmetrical ridges composed entirely of fine-grained sand south of Lake Traverse. These may be of eolian origin. The eskers in the area tend to be sandy but local pebble and cobble gravel facies are present.

Apart from minor unmappable pond deposits, no lacustrine or glaciolacustrine sediments were found in the study area.

Deposits of muck and peat occur in the numerous bogs and swamps in the area. Recent alluvial deposits of sand, silt, and minor gravel are found on the flood plains of many modern streams and often exceed 1.5 m in thickness. Minor amounts of organic material are commonly interstratified with the clastic alluvium, or are mixed with alluvial silt.

Economic Geology

Outwash and esker deposits can potentially supply material for road construction and maintenance over much of the area. However, many of the gravel deposits contain large amounts of oversized material which require primary crushing to produce sized coarse aggregate. Pit run material is suitable mainly for fill. Well sorted pebble gravels appear to be scarce. High water tables limit extraction in many of the outwash deposits, particularly in the Achray area.

Detailed work on the sand and gravel deposits outlined by the present survey is required to assess quantity

and quality. Alternate local material such as till and sand may be used in place of higher quality materials for fill or road subbase. Recent road building near North Branch Lake made extensive use of till as road base in cut and fill style construction. The better quality deposits should be reserved for uses requiring higher quality material.

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No. 18 Quaternary Geology of the Northwestern Part of Algonquin Park

R.S. Geddes[1]

Introduction

This study is part of a multi-year program designed to describe and map the surficial geology of Algonquin Park. The program was initiated at the request of the Regional Parks Co-ordinator, Algonquin Region Office, Ontario Ministry of Natural Resources, Huntsville, and is supported in part by Regional funding. Emphasis was placed on determining the Quaternary history and materials which could be used in the park's interpretive program, together with an assessment of aggregate resource potential within the park.

The area mapped is entirely within the northwestern part of Algonquin Park extending eastward to Longitude 78°30'W and southward to Latitude 45°45'N. This includes all of the Burntroot Lake map sheet (31 E/15), and parts of the South River (31 E/14), Kiosk (31 L/2), and Powassan (31 L/3) map sheets. M.J. Ford mapped the adjoining park areas to the east during 1982. Ford's work is reported elsewhere in this volume.

A major part of this area is accessible by logging roads, waterways, and a railway corridor. Detailed studies were undertaken along these access routes and supplemented by off-road traverses, air photograph interpretation, and fixed-wing aircraft reconnaissance.

[1]Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

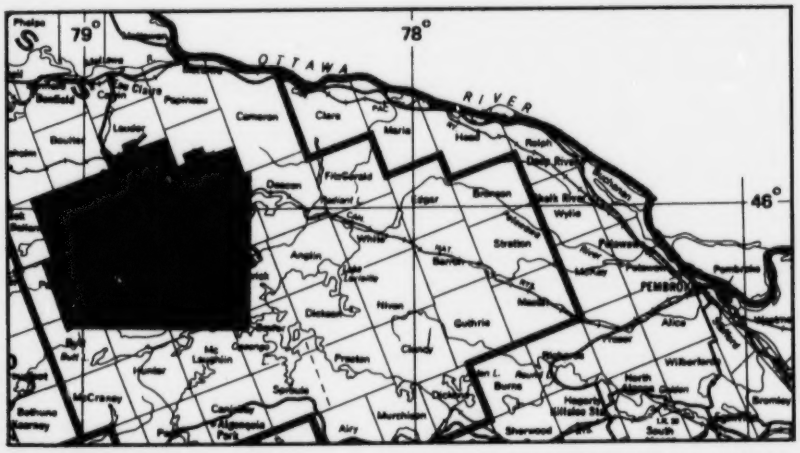
Physiography

The map-area is located within the Algonquin Highlands, a rugged area of moderate to high relief. The ground elevation gradually rises towards the south, with the lowest areas in the north at about 300 m above sea level, rising to a maximum of 530 m in the south. Drainage is predominantly eastward via a system of major lakes and river channelways, converging into the Petawawa River system.

Chapman (1975) shows the regional physiography of this area as being dominated by shallow till cover amongst major rocky uplands. In addition, a major kame moraine complex occupies the southern part of the map-area.

Bedrock Geology

The bedrock geology of this part of Algonquin Park is poorly understood, and has not been mapped in detail. Most of the area is underlain by migmatitic metasedimen-



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

tary biotite gneiss and granite gneiss. Quartz monzonite and minor anorthosite, which are prevalent east of the map-area, are found to a lesser degree.

An extensive set of northwest- to southeast-trending faults occupy most of the area, and are part of a much larger regional set related to the Ottawa Valley. Subsidiary northeasterly striking faults control much of the drainage in this area.

Quaternary Geology

The direction of the last (Late Wisconsinan) glacial advance over this part of the Algonquin Highlands is remarkably consistent. Numerous glacial striae were measured over the entire area and indicate an ice movement from the north-northeast in a direction which ranges from 200° to 220° azimuth. In contrast to the relatively simple glacial advance pattern, the deglaciation history of this area is complex. A wide variety of deposits associated with this event are found throughout the area.

A variety of till types have been mapped. The oldest Quaternary sediment found here is a compact, grey, silty sand till, deposited by a combination of lodgement and basal melt-out processes. It is found over the entire map-area, but is particularly prevalent and best exposed on the down glacial side of bedrock ridges. A loose, supraglacially derived till (ablation phase) is also common in the area. While much is of a melt-out nature, flow structures are commonly observed along steep bedrock slopes, and in association with ice-contact moraine. A younger, sandy till has been recognized in several isolated localities overlying post glacial fluvial sediments. The origin of this till is uncertain but it may indicate minor re-advances of the wasting ice sheet during deglaciaton.

Ice-contact deposits include kame complexes, small esker systems, deltaic sequences, and gravelly moraine. The latter forms a prominent morainal feature over the south and central part of the Burntroot Lake map sheet. It consists of coarse, poorly sorted gravels with a random, hummocky surface expression. It is intermixed with supraglacial till varieties. Kame complexes are found in several isolated areas, but are most prominent in a southwesterly trending belt north of Portal Lake, within the Burntroot Lake map sheet. Small, discontinuous esker systems are associated with several of these complexes. Ice-contact deltaic sequences are most common at lower elevations within the northwestern part of the project area.

Well sorted outwash sands and gravels occupy most of the lowland channels and valleys. The deposits are well bedded and flat topped. In the western and southwestern part of the map-area, gravel is the dominant material but this grades to sand in the deposits to the north and northeast of the area. The deposits in the latter areas grade upward into fluvial deposits representing outlet discharge from Lake Algonquin (Harrison 1972).

Glaciolacustrine deposits are confined to isolated lake basin areas in the northwestern part of the map sheet, particularly in the vicinity of Wilkes and Kioshkokwi Lakes. The deposits consist primarily of massive to weakly bedded sands, but isolated pockets of silt and clay rhythmites also occur. These deposits are related to the suggested proglacial lake phases of Harrison (1972) with waters being dammed to the northeast by the retreating ice front.

Accumulations of organic matter, in the form of peat and muck are widespread. They occur as isolated swamps or as large elongate bands associated with recent alluvium. This is particularly evident for the Nipissing River channel, which transects the map-area in a northeasterly alignment.

Land Use Applications

The Quaternary history of this part of Algonquin Park provides several features which are of interest to the park's earth science interpretive program. A few of these features include:

1. a complex history of meltwater drainage and outwash deposition in the southwestern area
2. well developed kame and kettle topography north of Portal Lake
3. ice-dammed lacustrine sequences to the northeast
4. the post glacial and Lake Algonquin outlet systems along the northern end of the map-area

Many of these features are inter-related with the canoe route networks.

Several areas of good aggregate potential have been encountered, including the areas and materials mentioned above. In addition, there are several other gravelly outwash systems in lowland valleys. Some of the supraglacial till deposits may also be of interest because of their widespread distribution.

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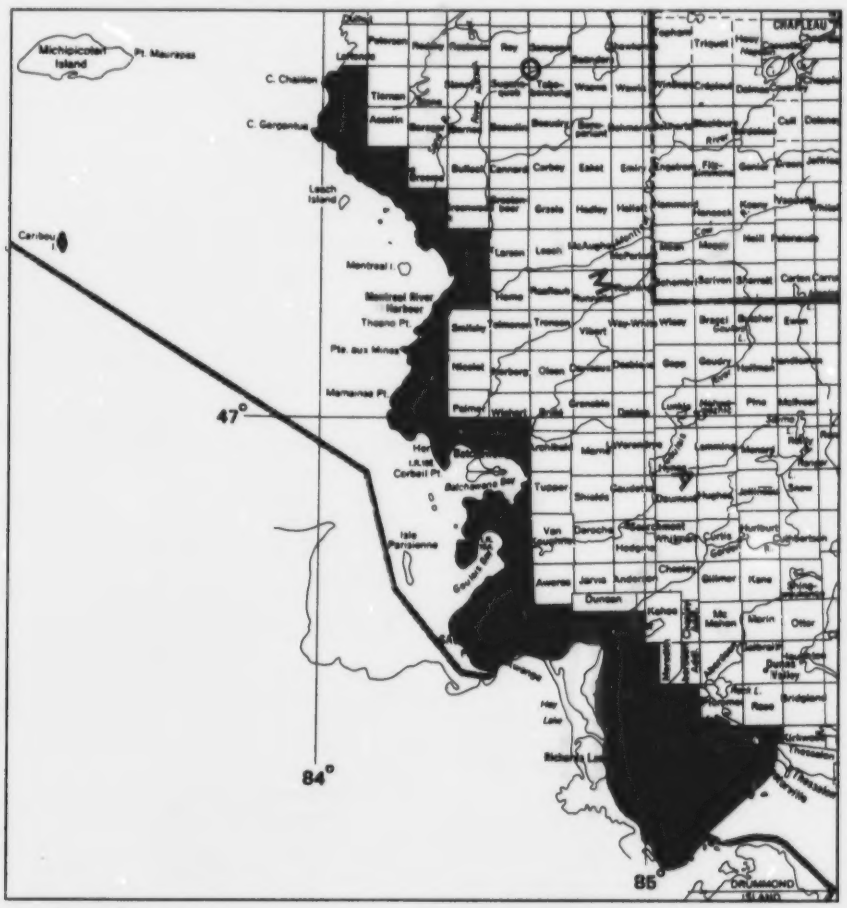
No. 19 Paleozoic Geology of the Sault Ste. Marie-St. Joseph Island Area

D.J. Russell[1]

Introduction

During the summer of 1982, field work was carried out in the Sault Ste. Marie-St. Joseph Island area to upgrade knowledge of the Paleozoic and supposedly Paleozoic sedimentary strata of the area. The main unit of interest in the Sault Ste. Marie area is the Jacobsville Sandstone, which has been assigned different ages by various authors, ranging from Early Keweenawan to Triassic. St. Joseph Island is almost entirely covered by glacial sediments, but these are underlain by Paleozoic rocks of the northern rim of the Michigan Basin. The known stratigraphy of the area is summarized in Table 1.

[1]Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

TABLE 1 EXPOSED POST MIDDLE KEWEENAWAN STRATIGRAPHY OF SAULT STE. MARIE-ST. JOSEPH ISLAND AREA

MIDDLE ORDOVICIAN
Gull River Formation
Shadow Lake Formation

UPPER CAMBRIAN
Munising Formation

UNKNOWN AGE – BETWEEN LATE KEWEENAWAN AND UPPER CAMBRIAN
Jacobsville Formation

UPPER KEWEENAWAN (?)
Mica Bay Formation (= Freda Formation?)

Location

The Jacobsville Sandstone occurs in patches over a large area of the mainland, extending from near Old Woman Bay in the north, to Sault Ste. Marie and Bar River in the south. Several islands in Lake Superior are also composed of the sandstone (e.g. Ile Parisienne and Montreal Island). Caribou Island in central Lake Superior (Longitude 85°50'W, Latitude 47°20'N) will be visited in 1983. Rocks of certain Paleozoic age are restricted to St. Joseph Island. Outcrops were visited in the areas covered by the following NTS 1:50 000 sheets: 41 J/4, 41 J/5, 41 K/1, 41 K/8, 41 K/9, 41 K/10, 41 K/15, 41 K/16, 41 N/1, 41 N/2, 41 N/7, and 41 N/10.

Jacobsville Sandstone

General Geology

This red sandstone unit is best exposed in large cliff sections on the Lake Superior shoreline of Michigan (Hamblin 1958) with only the far eastern edge of the outcrop belt extending into Ontario. During the 1982 field season, a large excavation in the Jacobsville Sandstone for a new hydroelectric development at the St. Marys River Locks was accessible. This, together with the abundant subsurface information made available by the owners (Great Lakes Power Limited) through the consultants (Acres Consulting Services Limited), was helpful in the interpretation of the depositional environment. As indicated above, there is considerable dispute about the age of the Jacobsville Sandstone. Hamblin (1958) concluded that it was of Early or Middle Cambrian age, based on indirect evidence against a Late Keweenawan age, and an observed unconformity with overlying Upper Cambrian sediments. Babcock (1975) has suggested a Lower or Middle Keweenawan position for the sandstone, from observations of apparently interbedded lavas. Roy and Robertson (1978) determined from paleomagnetic work that the unit was of Late Keweenawan age (about 1100 million years) on the Keweenaw Peninsula, but was significantly younger near Sault Ste. Marie. Uncertainty over the age of the unit may be due in part to confusion concerning the stratigraphic correlation of various sections from the extensive outcrop area. The Jacobsville Sandstone is underlain in Michigan by the Freda Formation, a thick sequence of lacustrine arkosic sandstones and red silty shales of Upper Keweenawan age (Hamblin 1961). Hamblin shows the deposits around Sault Ste. Marie as Freda Formation. Subsequently, most authors have regarded the Ontario deposits as belonging to the Jacobsville Formation (Frarey 1977; Liberty 1980). A small series of outcrops, grouped together as the Mica Bay Formation by Giblin (1974), in the northern part of the area has been correlated tentatively with the Freda on lithologic grounds. P.E. Giblin (Resident Geologist, Ontario Ministry of Natural Resources, Sudbury, Ontario, personal communication, 1982) also has observed the mudstone and arkosic sandstone of the Mica Bay Formation underlying Jacobsville Sandstone with a gradational contact in a borehole core from Mica Bay itself. Hamblin (1958), however, suggests that there should be an angular unconformity between the two formations. The exact stratigraphy of those sediments is therefore not yet determined; whether it is possible to do so is doubtful due to poor outcrop and the small thickness exposed relative to the total section (at least 500 m was determined in a drillhole at Goulais Bay).

In this work, all the red arenaceous sediments younger than the Keweenawan lavas and older than the Upper Cambrian Munising Formation are regarded as the Jacobsville Formation. In general, the rock is a very fine to fine-grained, moderately well to well sorted red hematitic quartz arenite, above a thin basal conglomerate, with some green mottling and white bleached beds. Sedimentary structures and other features suggest a fluvial and deltaic origin. On Montreal Island and near Old Woman Bay, the unit is conglomeratic, and more poorly sorted. In many sections, red mud pebble intraformational conglomerates are present, but rarely exceed 100 mm in thickness.

The Mica Bay Formation is a sequence of siltstones, mudstones, and arkoses with a thin basal conglomerate. During the 1982 field season, previously unrecorded outcrops found near Cape Gargantua consist of red silty mudstone, with rounded pebbles of granitic rocks and red mudstone, in unconformable contact with Early Precambrian (Archean) granites. This lithology is very similar to that of the Freda Formation of the Keweenaw Peninsula, and may represent the source of the red mudstone clasts present in the Jacobsville.

Structural Geology

The area of original sandstone deposition was probably controlled by faulting contemporaneous with sedimentation. Giblin (1969) postulated that the northern boundary of the sandstone in Batchawana Bay was a fault. The southern boundary is also faulted, causing minor folding near the fault plane along Havilland Shores, and along

Highway 17 north of Havilland. This faulting may be syn-depositional, but the fault due east of Goulais River is clearly post-diagenesis, since the basal conglomerate boulders are highly fractured. Away from contacts, the dips are gentle, usually to the west with a maximum of 15°.

Economic Geology

Apart from an unsuccessful investigation by a consortium led by Ranwick Mines Limited into the possibility of Elliot Lake-type uranium deposits in the basal conglomerate, the Jacobsville Sandstone has not been of great economic interest. It is generally too weak and porous for use as aggregate, although it has been used extensively in the area as building stone.

Post Jacobsville Strata

General Geology

On the northern rim of St. Joseph Island, there are a few outcrops of Cambrian and Ordovician rocks. The Upper Cambrian Munising Formation, although very poorly exposed on the south side of Campement d'Ours Island, is identifiable due to its distinctive well sorted pure white quartzose lithology (Hamblin 1958). Close to this outcrop, and previously correlated with it, is an outcrop of variably dolomitic poorly sorted green and grey medium-bedded sandstone. However, other outcrops in the area show it to be overlain conformably by shales and shaly limestones with a Middle Ordovician fauna. The sandy unit is therefore correlated with the Shadow Lake Formation of southern Ontario (Liberty 1969), and is equivalent to the Au Train Formation of Michigan. The terrigenous rocks described above are overlain by carbonate rocks equivalent to those of the Simcoe Group of Liberty (1969). The few outcrops near Gravel Point, and the single quarry near the north shore of the island allow identification of the Gull River Formation. In the old quarry, this is a grey bioclastic limestone with thin shale interbeds overlain by a light blue-grey lithographic or sublithographic sparsely fossiliferous limestone. At Gravel Point, medium-bedded crystalline dolostones are interbedded with these rock types. These shoreline outcrops exhibit an unusually prolific fauna including large-shelled brachiopods, many tabulate corals, and a distinctive gastropod/nautiloid assemblage. Further detailed differentiation of Ordovician, and possible Silurian, units is impossible due to lack of outcrop. However, drillcores from the south of the island show an Ordovician sequence similar to that on Manitoulin Island. The Silurian Manitoulin Formation may also be present.

Structural Geology

The structure of the Cambrian strata is difficult to ascertain but they may be in faulted contact with the Precambrian rocks to the north. The Ordovician strata have the Michigan Basin as their structural control and therefore dip gently to the south.

Economic Geology

The weathering product of the Munising Sandstone has been investigated as a source of silica (Hewitt 1963). Beyond the abandoned quarry mentioned above, the Paleozoic strata on St. Joseph Island are of low economic interest.

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No. 20 Study of Surface Stress-Release Phenomena, Southern Ontario

D.J. Russell[1], J. Graham[2], and Owen L. White[3]

Introduction

The presence of high horizontal stresses in the bedrock of Southern Ontario at very shallow depths has been established since 1973 (White *et al.* 1973). *In situ* stress measurements at various sites around Lake Ontario have yielded values for the maximum horizontal principal stress of up to 14 megapascals (Lee 1981). This phenomenon is relevant in the design of structures emplaced in rock excavations (e.g. tunnels, underground storage facilities, and electricity generating structures). The natural features which are symptomatic of this state of stress are elongate anticlines or thrust planes affecting only the surface layers of bedrock (and the overlying drift cover, if any). These have been termed "pop-ups". Similar features observed in the floors of many quarries have occurred after excavation of the overlying rock as a response to vertical stress release and are termed "quarry floor buckles". Fieldwork this summer involved visiting numerous examples of known pop-ups and quarry floor buck-

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[2]Student, Geology Department, Queen's University, Kingston, Ontario.

[3]Chief, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

TABLE 1 ORIENTATION DATA FOR "POP-UPS", SOUTHERN ONTARIO

NUMBER	LOCATION	TYPE	TREND (°)	REFERENCE
1	Lorne Park, Toronto	fold	170	White *et al.* (1973)
2	Oakville	fault	060	White *et al.* (1973)
3	Oakville	fault	135	White *et al.* (1973)
4	Oakville	fold	100	White *et al.* (1973)
5	Tullamore	fold	070	White *et al.* (1973)
6	Woodbridge	fold	028	White *et al.* (1973)
7	Oakville	fold	160	White *et al.* (1973)
8	Burlington	fold	116	White *et al.* (1973)
9	Clairville	fault	000	White *et al.* (1973)
10	Zimmerman	fault	000	White *et al.* (1973)
11	Oakville	fold	020	C. Mirza (pers. comm.)
12	Toronto	fold	030	C.R. Kustra (pers. comm.)
13	Scarborough	fold/fault	120	P.F. Karrow (pers. comm.)
14	Fenelon Falls	fold	125	P. Finamore (pers. comm.)
15	Fenelon Falls	fold	115	P. Finamore (pers. comm.)
16	Fenelon Falls	fold	115	P. Finamore (pers. comm.)
17	Fenelon Falls	fold	105	P. Finamore (pers. comm.)
18	Fenelon Falls	fold	115	P. Finamore (pers. comm.)
19	Fenelon Falls	fold	105	P. Finamore (pers. comm.)
20	Fenelon Falls	fold	100	P. Finamore (pers. comm.)
21	Fenelon Falls	fold	103	P. Finamore (pers. comm.)
22	Fenelon Falls	fold	128	P. Finamore (pers. comm.)
23	Wellman	fold	037	Winder (1954)
24	Woodview	fold	150	B.A. Liberty (pers. comm.)
25	Young's Point	fold	135	C.G. Winder (pers. comm.)
26	Hoard	fold	120	B.A. Liberty (pers. comm.)
27	Menie	fold	000	B.A. Liberty (pers. comm.)
28	Pte. St. Anne	fold	120	B.A. Liberty (pers. comm.)
29	Toronto	fold	066	E. Magni (pers. comm.)
30	Ottawa	fold	147	J. Adams (pers. comm.)
31	Delta	fold	025	R. Wolf (pers. comm.)

TABLE 2 ORIENTATION DATA FOR QUARRY FLOOR BUCKLES, ST. LAWRENCE LOWLANDS AREA

NUMBER	LOCATION	ORIENTATIONS (°)	REFERENCE
1	Milton	045/141	White *et al.* (1973)
2	Ottawa	136/082/057	J. Adams (pers. comm.)
3	Terrebonne	355	Saull and Williams (1974)
4	St. Eustache	155/90	Saull and Williams (1974)
5	Marmora	135	Lo (1978)
6	Roblindale	135	D. Carson (pers. comm.)
7	Cornwall	110/(060,155,170)	D. Williams (pers. comm.)
8	Warren	095	D. Williams (pers. comm.)
9	Uhthoff, Orillia		P. Finamore (pers. comm.)

les, and detailed surveying and structural geological mapping of one quarry floor buckle (near Bell's Corners, Ottawa) and two pop-ups (near Young's Point and Wellman).

Regional Studies

Since their identification, shallow high horizontal stresses have been taken into account in the engineering design of excavations in rock. However, study of the rock features and associated stresses has continued, since the state of crustal stress affects the occurrence of earthquakes. The magnitude, distribution, and orientation of the stresses and resulting deformations will give indications of the origin of the stresses, which in turn affect the seismic potential of the area. Tables 1 and 2 list all the known features ascribed to high horizontal stresses. One pop-up (number 31 in Table 1) and three buckles (numbers 7, 8, and 9 in Table 2) have not been previously reported in the literature. There is a clustering of the orientation of the long axes of pop-ups and the strike of thrust surfaces in a direction trending approximately 130°. This evidence, combined with some stress measurements, suggests that the stress field is a systematic, regional feature imposed by crustal processes, rather than one caused by storage of lateral stresses resulting from ice-sheet loading. However, the detailed observations described below cast doubt on the extent to which this generalization can be taken.

Site-Specific Studies

Two weeks were spent at the MacFarland quarry, near Bell's Corners, Ottawa, making detailed structural geological observations on the quarry walls and determining the exact morphology of quarry floor buckles at that site, by accurate surveying. The major buckle trends at 136° for 250 m across the quarry floor. Along its crest there is frequent evidence of mineralization, commonly calcite and pyrite. At the southern end of the buckle, there is a mineralized normal fault trending exactly the same direction as the buckle, with 5 m displacement to the northeast. This displacement decreases along the trace of the fault within the quarry and is less than 1 m at the north wall of the quarry. The location and orientation of the buckle is thus obviously controlled by a pre-existing fracture.

Short periods of fieldwork were spent at the Young's Point and Wellman pop-ups performing similar work to that done at Bell's Corners. At each of these sites, major fractures were observed in the rock surrounding the pop-ups, with trends paralleling that of the axes of the pop-ups. At Wellman, the crest of the pop-up was marked by a joint which was heavily affected by solution weathering. There are indications, therefore, that the orientations of near-surface stress release phenomena may be functions of both the character of the stress field and the pre-existing discontinuities.

A. Pahl, of the Rock Mechanics Section of the Federal Republic of Germany Geological Survey, was escorted on a field trip to the three sites reported above, and offered many useful comments concerning the timing of natural pop-ups relative to the development of karst features.

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No. 21 Aggregate Resource Inventory of Southern Ontario

Staff of the Aggregate Assessment Office[1]

Introduction

Field work was conducted in several areas of southern Ontario during 1982 as part of the Aggregate Resources Inventory Program. Field investigation is an integral step in the preparation of each aggregate report. The results of field activities undertaken in 1982 will be published in appropriate Aggregate Resources Inventory Papers. The main areas involved in field investigations were:

1. Grey County
2. Simcoe County
3. Perth and Huron Counties
4. Middlesex and Lambton Counties
5. Regional Municipality of Durham and Peterborough County
6. Regional Municipalities of Haldimand-Norfolk and Niagara

Field investigations consisted of the following activities: examination of potential aggregate deposits, existing pits, quarries, natural and man-made exposures, as well as subsurface auger drilling. All active and abandoned pits were investigated and at each site the following observations were made: face height, percentage of gravel and sand, and the presence of deleterious material such as chert, shale, clay, silt, and oversized boulders. Other information gathered during the pit investigations included the intended uses of the granular material and the presence of stock piles, water filled ponds, crushing plant, and rehabilitation work. Abandoned pits were evaluated also to provide additional information on resource areas. Estimates of the amount of material previously extracted in these pits were made to enable resource tonnage calculations. Active and abandoned quarries were also visited; at these sites, the height of the face was noted, as well as bedrock geology, and the presence of deleterious materials. The purpose of the field investigations was to confirm and add to information gathered from various sources such as existing geological reports and maps, data from files of the Ontario Ministry of Transportation and Communications, and water-well data from the Ontario Ministry of the Environment.

In areas where little pre-existing data were available or where the presence of buried granular material was suspected, drilling and geophysics work was undertaken. The combined use of a small portable drill rig and geophysical equipment (conductivity and hammer seismic) provided more information, permitting a better means of assessment of potentially significant sand and gravel deposits.

A commercial drill rig was contracted to undertake drilling and sampling in the Fonthill area, in order to re-evaluate the long range potential of this complex ice-contact deposit, representing the most significant sand and gravel source in the Regional Municipality of Niagara.

Grey County

In 1982, field investigations which included the use of subsurface drilling and geophysics were carried out in Sullivan, Holland, and Derby Townships, in Grey County. The Banks and the Gibraltar Moraines (Feenstra 1975) traverse Holland and Sullivan Townships parallel to one another, in a northeasterly direction, with the Gibraltar Moraine being the southernmost of the two. The Singhampton Moraine (Feenstra 1975) also crosses the southeastern corner of Holland Township. The areas between the three moraines have been modified by glacial meltwaters associated with the formation of the Gibraltar Moraine, during the melting of the 'Elma Ice' of the Georgian Bay lobe. As a result, Holland Township contains numerous outwash deposits which extend, to a lesser degree, into Sullivan Township. A number of esker and ice-contact stratified drift deposits also occur in northwestern Sullivan.

The Tara Moraines trend northwest across Derby Township (Sharpe and Edwards 1979). They are composed of ice-contact stratified drift and many pits have been developed in the moraines. In addition to the moraines, a number of other ice-contact and outwash deposits add to the resource base of the township.

Simcoe County

The aggregate potential of the townships of Vespra, Essa, Tosorontio, Innisfil, West Gwillimbury, and Tecumseth in the central and southern half of Simcoe County was investigated in 1982. The most important gravel-bearing deposits are associated with the abandoned

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shorelines of glacial Lake Algonquin (Deane 1950; Burwasser and Cairns 1974; Gwyn and White 1973). Subsurface drilling and results from geophysical investigations were useful in assessing the resources of crushable aggregate, particularly in outwash gravel deposits. Subsurface drilling and seismic refraction work was also carried out in ice-contact sediments near Rich Hill to investigate the potential for buried aggregate. The western part of the Bass Lake kame moraine was also evaluated by means of field investigation and drilling to delineate areas of crushable aggregate.

Perth and Huron Counties

The townships of Wallace, Elma, and Logan in Perth County were assessed in 1982. The field investigation included the use of subsurface drilling and geophysics to determine the gravel content and depth of various deposits. The most significant deposits in the townships were formed as the 'Elma Ice' of the Georgian Bay lobe disappeared from the area. In the north, numerous interconnecting meltwater channels and small ice-contact stratified drift and esker deposits are the chief sources of sand and gravel. To the south, sand and gravel is found in a series of esker and ice-contact stratified drift complexes.

A similar investigation was carried out in Hullett Township (Huron County). The major gravel-bearing deposit in the township is the Wawanosh Moraine (Cooper *et al.* 1977), which is exposed in the western third of the township and is known to underlie the entire township at depth. Formed by the interaction of the Georgian Bay and Huron lobes, the moraine contains ice-contact stratified drift, including two esker-kame complexes. Outwash gravels located along the South Maitland River, which were formed by the drainage of meltwaters during the recession of the Huron lobe, are also considered to be significant.

Middlesex and Lambton Counties

Three townships within Middlesex County were field checked. These included McGillivray, East Williams, and West Williams Townships. Licenced pits have been established in glaciolacustrine, glaciofluvial, and ice-contact stratified drift deposits. Sand and gravel supply in these areas is limited mostly to fine aggregate. Although some deposits contain small pockets of slightly higher stone content, sources of good quality crushable aggregate are generally lacking in these townships. Despite the obvious quality and quantity limitations, these deposits should be recognized as important local sources of granular material.

Thick drift cover overlies much of the bedrock in these townships, excluding the possibility of using the Dundee Formation as a source of crushed stone. However, shale from the Hamilton Group is mined near the shore of the Ausable River in West Williams Township for the production of tile in Parkhill.

Field checking of the aggregate-bearing deposits of Bosanquet Township, Lambton County revealed a similar general scarcity of high quality, crushable aggregate. Aggregate within Bosanquet Township was found in a succession of raised shorelines deposited at the margins of several former glacial lakes. Minor resources were also found in small outwash deposits along the Ausable River. The sandy texture of the deposits reflects the nature of the fine-grained bedrock and glacial till from which the material was reworked. A total of 15 pits are licenced to extract the material.

Extraction of the Hamilton Group also takes place in Bosanquet Township. The shale is used for the manufacture of drainage tile. Because the overburden cover of the shale is thin in several parts of the township, extraction could take place in numerous localities.

Regional Municipality of Durham and Peterborough County

Field investigations were carried out in the Township of Scugog as well as in Cavan, North Monaghan, and South Monaghan Townships. The largest area of high aggregate potential is found in sections of the Oak Ridges Interlobate Moraine (Chapman and Putnam 1966). Good quality crushable gravel can be obtained from outwash gravels from the southwestern part of the Township of Scugog. Pockets of coarse aggregate can be located in other portions of the moraine also. The additional deposits of potential significance include ice-contact stratified drift deposits in the Blue Mountain area and in the southern extension of the Blackwater esker segment. Part of the Oak Ridges Moraine also traverses southern Cavan Township. Here it consists of sandy aggregate, although pockets of gravel are present locally. North of the moraine a number of ice-contact stratified drift deposits are present. With content similar to that of the moraine, they contain predominantly sand, with isolated gravel occurrences. A kame deposit containing crushable gravel is situated along the township's northern boundary. Several test holes were placed in the deposits north of the moraine to determine their resource potential. North Monaghan and South Monaghan Townships have several ice-contact and outwash deposits which contain generally sandy aggregate.

Regional Municipalities of Haldimand-Norfolk and Niagara

Two municipalities within the Regional Municipality of

Haldimand-Norfolk were investigated, namely the towns of Dunnville and Haldimand. Although surficial sand and gravel resources are limited in the two areas, they contain considerable bedrock resources. A similar situation exists in the Regional Municipality of Niagara, as it also has a limited supply of surficial sand and gravel, but has substantial bedrock resources. The exception is a kame deposit in the Fonthill area which is capable of supplying a range of aggregate products. This deposit was explored in further detail using a large drill rig to delineate the extent and depth of suitable aggregate material as well as to better understand the mode of deposition of the kame sediments. Data for other municipalities within the Regional Municipality of Niagara have also been compiled.

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No. S11 Quaternary Geology of the Kamiskotia Lake-Pamour Area, District of Cochrane

James A. Richard[1]

THIS PROJECT WAS FUNDED BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS THROUGH THE NORTHERN ONTARIO GEOLOGICAL SURVEY (NOGS) PROGRAM.

Introduction

Field mapping and stratigraphic investigations of the study area were initiated in 1980 and completed during the 1982 field season. The 2044 km^2 study area is situated between Latitudes 48°30'N and 48°45'N, and Longitudes 81°00'W and 82°00'W (NTS 42 A/11, 12). All but the northernmost townships and western half of the Kamiskotia Lake area lie within the jurisdictional limits of the City of Timmins. The community itself, located 3 km south of the Pamour area, is the heart of the Porcupine mining camp.

Data was obtained through the examination of exposures along ground and watercourse traverses, and through the use of soil probing equipment. Helicopter traverses aided in sampling the less accessible, northern parts of the study area. Surficial units were delineated using 1:15 840 and 1:63 360 scale air photographs. Several hundred borehole logs provided excellent data on subsurface stratigraphy.

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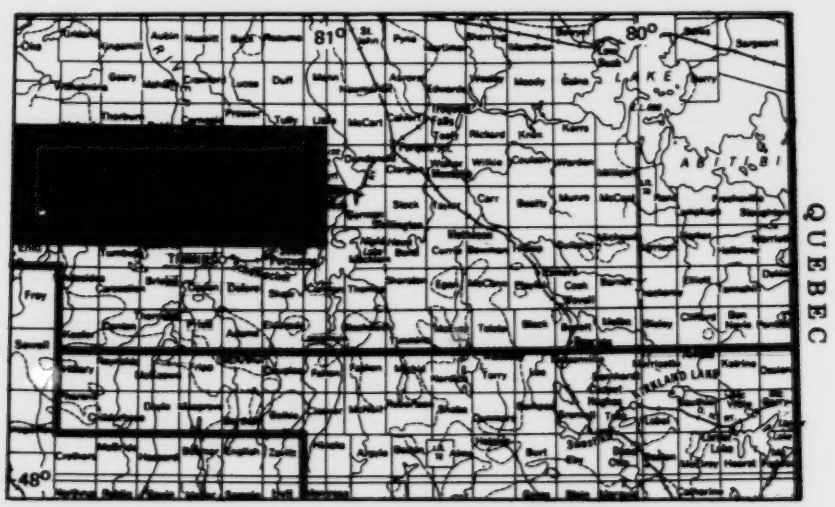
Bedrock Geology

General summaries are given by Ferguson (1968), Pyke (1982), and Goodwin (1979) in addition to the numerous township preliminary maps available.

Early Precambrian (Archean) rocks belonging to the Abitibi Belt of the Superior Province are found throughout the study area. Metasediments of the Porcupine Group occupy the central Pamour area, flanked to the south by auriferous mafic metavolcanics of the Tisdale Group. Rhyodacitic flows and iron formation of the Deloro Group lie south of the Destor-Porcupine Fault which trends across Whitney and Cody Townships. Intercalated formations of mafic to felsic metavolcanics, hosting stratiform massive sulphide mineralization, dominate the eastern Kamiskotia Lake and northern Pamour areas. Pyke (1982) tentatively correlated these rocks with those of the Deloro Group. Trondhjemites and quartz monzonites of the Groundhog Dome Batholith underlie the western Kamiskotia Lake area. Mafic to ultramafic dikes and sills intrude metavolcanic sequences throughout the study area. The Kamiskotia mafic intrusive complex, centred in Robb



LOCATION MAP Scale: 1: 1 584 000 or 1 inch to 25 miles

and Massey Townships, is an example (Wolfe 1970). North-trending diabase dikes of Early to Late Precambrian age are ubiquitous, and particularly numerous in the eastern Kamiskotia Lake area.

Physiography

The study area can be divided into 2 broad physiographic zones. Level to gently rolling expanses of the Great Northern Clay Belt typify most of the Pamour area and the north-central Kamiskotia Lake area. Bedrock outcrop and esker complexes provide the only exceptions to an otherwise monotonous, planar landscape that is underlain by varved clay and clay till. In the southern half of the Kamiskotia Lake area, the Early Precambrian (Archean) basement rises to prominence above the clay plain, as it does along the southern margin of the Pamour area. This terrain displays a rugged topography which is thinly veneered by drift. Abrupt relief changes of up to 100 m occur in these bedrock uplands positioned between 298 m and 396 m above sea level. By contrast, the clay plains range between 260 to 305 m above sea level and exhibit relief changes of less than 15 m.

Quaternary Geology

Early to Late Wisconsinan glacial deposits and features of the Kamiskotia Lake-Pamour area record the advance/retreat of the Laurentide ice, the development of proglacial Lake Ojibway, and the late-glacial readvance of the Cochrane ice lobe.

Morphologic ice-direction indicators such as crag and tail forms, roche moutonées, as well as striae and till macrofabric data, indicate a movement of the ice sheet in the direction 175° to 185°.

Main Wisconsinan glaciation is represented by Matheson Formation Till (Hughes 1959), the oldest stratigraphic unit exposed in the area. Three till facies of this unit are recognized according to lithologic and geochemical parameters: 1) overconsolidated lodgement till, 2) normally consolidated basal meltout till, both of which exhibit a moderately stony, gray, sandy silt matrix and local lithologies, and 3) unconsolidated supraglacial meltout till. The lattermost, derived from more distant up-ice sources, is typically found as a coarse, stony capping over ice-contact sediments. Buried lodgement till has been observed in section to thicknesses of 10 to 15 m in the Pamour area. Over bedrock-controlled terrain, till accumulations are generally 1 to 3 m thick.

Six major esker systems, ranging from 30 km to more than 100 km in length, trend south-southeasterly across the study area as follows: 1) Fortune esker, south through Fortune and Enid Townships; 2) Dana esker, bisecting the entire Kamiskotia Lake map-area; 3) Kamiskotia esker, in central Thorburn, Loveland, and Robb Townships; 4) Grassy esker, in Godfrey Township; 5) Murphy esker, bisecting the Pamour map-area, and 6) Ice Chest esker, across central Evelyn and Matheson Townships. Prominent esker crests (averaging 20 to 25 m in height) are composed of subglacial core gravel. They are commonly flanked and/or buried by fine-grained subaqueous outwash sands which reflect ice-marginal meltwater debouchment into proglacial Lake Ojibway.

Glaciolacustrine sediments of the Barlow-Ojibway Formation (Hughes 1959) cover virtually all terrain below 295 m above sea level. Varved clays attaining thicknesses between 25 to 35 m are typical of the Pamour map-area. Former shoreline levels occur in well developed sets at 295 m, 305 m, 311 m, and 323 m above sea level. Glacial deposits below the highest water level have been variably reworked by the regressive waters of glacial Lake Ojibway and eolian activity.

Silty clay till (exhibiting blocky to columnar jointing) and minor glaciolacustrine sediments of the Cochrane readvance mantle northern sections of the study area. The southern limit of this readvance is located along the Mattagami River in Jamieson Township. Cochrane Till is dominantly composed of a stone-poor flow till facies, which supports the concept of ice readvance and wastage into isolated basins of late-glacial Lake Ojibway. No distinct end moraines of the Cochrane readvance have been observed. High percentages of Paleozoic carbonate till clasts indicate the James Bay Lowland as the source area, which requires the Cochrane lobe to have readvanced a minimum of 220 km southward.

Economic Geology

Aggregate resources of the Pamour map-area have previously been surveyed by Hunt (1982). Extraction operations are presently concentrated along Highway 655 in the Murphy esker where significant reserves of crushable material are available for the foreseeable future. The Ice Chest esker, and in particular, the Fortune, Dana, and Kamiskotia esker systems contain larger reserves of high-quality gravel. These resources will eventually be required when aggregate sources close to major centres become depleted. In clay plain areas, the discovery of new aggregate resources is difficult because the esker and ice-contact deposits are buried beneath fine-grained outwash, glaciolacustrine clays, and clay till.

Engineering Geology

Severe slope stability problems exist in areas underlain by glaciolacustrine clays. Rotational block slumping is typical along steep river and lakeshore faces. Mass flows occur on over-steepened excavation slopes when dewatering is inadequate.

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No. S12 Quaternary Geology of St. Joseph Island, Algoma District

P.F. Karrow[1]

THIS PROJECT WAS FUNDED BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS THROUGH THE NORTHERN ONTARIO GEOLOGICAL SURVEY (NOGS) PROGRAM.

Introduction

St. Joseph Island is in northwestern Lake Huron, and lies about 35 km southeast of Sault Ste. Marie. The island extends from Latitude 46°04′N to 46°19′N, and Longitudes 83°46′W to 84°07′W. Mapping of the Island was completed in the spring of 1982 and a preliminary map with marginal notes is to be published. Small scale maps of the Island have been published by Chapman and Putnam (1966) and VanDine (1979).

General Geology

Except for a small area at the northern edge of the island that is underlain by Precambrian Huronian metasediments, the bedrock is of Paleozoic age (Giblin and Leahy 1979). This consists of Cambrian sandstone, particularly prominent around Gawas (Desjardins) Bay and on Campement d'Ours Island, and of Ordovician carbonates and shales, which have a gentle dip to the south. Bedrock outcrops intermittently from near the Highway 548 entrance bridge to Recollect Point, near and along the northeastern shore.

Quaternary deposits consist of: red to buff, sandy to gravelly till in the form of drumlins, small end moraines, till plain, bouldery to cobbley beach gravel and sand, and lacustrine red and gray clay which is particularly extensive in the northwestern agricultural part of the Island. Extensive, shallow, organic deposits occur on the lower lacustrine terraces and plains. A prominent tract of sand dunes extends for several kilometres west of Twin Lakes (Hilton Lake). Most of the surface deposits have a lacustrine origin attributed to reworking of glacial deposits during submergence by the various levels of glacial Lake Algonquin and the Nipissing and Algoma stages.

Glaciation of the Island was by ice moving nearly due south. Only above the Algonquin shore does any of the glacial surface remain; it forms the highest part of the Island, locally known as "the Mountain" and has an area of only 5 by 4 km. During the retreat of the ice front all but "the Mountain" was submerged by Lake Algonquin,

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LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

which built a prominent gravel beach and shorecliff that have been isostatically tilted up to the north (Karrow 1982). Successively lower levels formed numerous bars and shorecliffs down to below the present Lake Huron level. Isostatic rebound of the post-Algonquin outlet at North Bay again raised water to form the Nipissing stage, whose shoreline cross-cuts the earlier ones and is particularly prominent along the western side of the Island.

Economic Geology

Small quarries are located in the Ordovician limestone near the Highway 548 bridge, at Canoe Point, and at Gravel Point, but have little economic importance. There have been a few exploratory holes drilled for petroleum (Paleozoic) and other minerals (Precambrian), but there is no active exploration at the present.

The chief economic product of Quaternary age is sand and gravel from the extensive raised beach deposits. Large reserves remain, with most of the gravel finding only local use. The gravel is petrographically of good quality, being dominantly of Precambrian rock types, but the abundance of boulders makes crushing commonly necessary for most purposes. Substantial volumes of clay are present but have not been exploited.

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No. S13 Report on the Sedimentology and Provenance of Sediments in Eskers in the Kirkland Lake Area, and on the Finding of Kimberlite Float in Gauthier Township

C.L. Baker[1]

THIS PROJECT WAS PART OF THE KIRKLAND LAKE INITIATIVES PROGRAM (KLIP) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NORTHERN AFFAIRS UNDER THE COMMUNITY AND RURAL RESOURCE DEVELOPMENT SUBSIDIARY AGREEMENT.

Introduction

The fifth year of Quaternary studies, completed under the Kirkland Lake Initiatives Program (KLIP), centred on examining the stratigraphy and sedimentology of the Highway esker, west of Kirkland Lake. The study was designed to complement the work undertaken in 1981 on the Munro Esker (Baker 1981). The previous work had shown the presence of distinct sedimentary facies along the esker, each with a unique stratigraphy. The present work on the Highway esker was undertaken to assess whether the stratigraphy and sedimentation patterns found in the large Munro Esker are present in smaller eskers. Preliminary findings on the source and transportation of material in glaciofluvial systems based on the 1981 work, are to be compared and, if possible, expanded upon with the addition of this year's data.

The principal objective of the program is to develop methods by which glaciofluvial systems, particularly eskers, may be used as a prospecting tool.

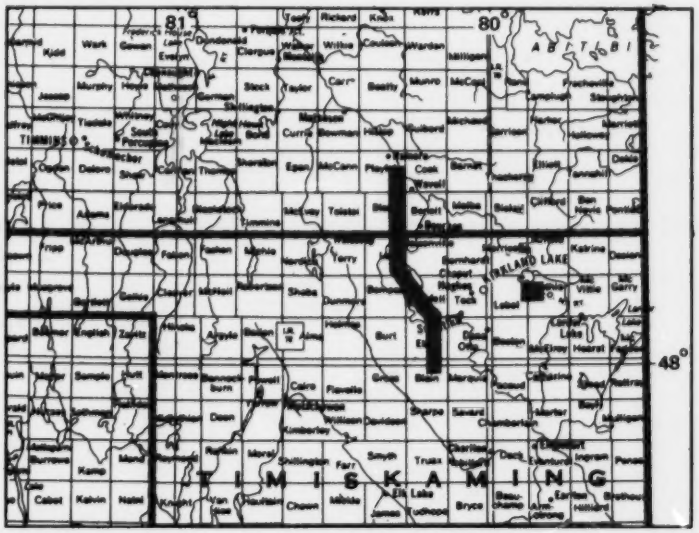
[1]Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

Acknowledgments

Field work was done by the author with the assistance of J.S. Paterson. The author wishes to thank individuals and companies who took part in discussions, provided access to property, and allowed sampling by trenching. Particular thanks are extended to Harry Jansen, Bob Kasner, Bill Thorpe, the Ontario Ministry of Transportation and Communications, and Nelson Brothers Construction Company Limited (Kirkland Lake).

Methods

Initial work on the Highway esker was completed in 27



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

gravel pits located between Blain and Playfair Townships. Manual cleaning of selected faces within the pits was completed and detailed notes were taken. Physical features including texture, rounding, and sorting, in addition to sedimentary structures were used to map the units present. Note was taken of the vertical and lateral facies of these units.

Mechanical equipment was used to expose fresh material on faces with heavy slump cover. Equipment used included Case 580B and 580C backhoe-loaders fitted with an "extendahoe" option. Up to 10 m of slump at a pit face could be removed in approximately 20 to 25 minutes. An additional 5 to 10 minutes was required to dig a 3 to 4 m trench at the base of the section (water table permitting) to increase exposure. This procedure allowed the sedimentary facies present in the esker to be determined and the position of the ice during deposition to be reconstructed.

To provide sampling continuity along the esker, sites between gravel pits were sampled by trenching with power equipment. Trenches were dug to a depth of 2 to 3 m, depending on local topography and material cohesion. This permitted sampling of unoxidized, unweathered sediments, and a viewing of the sedimentary structures.

In 68 hours of equipment time, 40 trenches were dug and 29 faces in 17 pits were cleaned along a 47 km long section of the esker. Access was provided by highways, township roads, pipeline access routes, and abandoned forestry roads. Route selection and trench locations were predetermined using aerial photographs and Quaternary geological maps (Baker 1980; Baker *et al.* 1980).

Sample Collection and Processing

The number of samples obtained in a gravel pit depended on the type, size, and variation of the units present. Only one sample was collected per backhoe trench. Gravel units were field split using a 4 mesh (4 mm) sieve. Two samples resulted: one of gravel, with pebbles up to 8 cm; and one of the fine-grained fraction, predominantly sand, which weighed 7 to 8 kg. Only one sample was taken from sandy units or units containing a minor amount of gravel.

The gravel fraction was washed and 100 to 120 clasts > 1.5 cm in length, were split and identified. A total of 131 sand samples will be processed to separate mid-density (2.8 to 3.3 S.G.) and heavy mineral (< 3.3 S.G.) assemblages. These fractions are then screened into plus and minus 125 micron subsamples. In samples with sufficient fine material a split of the – 230 mesh (– 63 microns) size range was also collected. Geochemical analysis of the – 230 mesh material and the heavy minerals is expected to be completed by early 1983. Portions of the mid-density and heavy mineral sample suites will be retained for reference and visual examination by interested parties.

Mapping Results

The major depositional environments of the Highway esker are: 1) the crest which was formed in a conduit or tunnel extending back from the ice front, and 2) ice-marginal deltas and subaqueous fans built out into the glacial lake which fronted on the ice. Locally, these glaciofluvial sediments show evidence of having been deposited on underlying ice sheets or blocks and subsequently let down.

The Highway esker crest or ridge is composed of a series of stacked sedimentary cycles similar to those found in the Munro Esker (Baker 1981).

The ice-marginal deltas, recognized only in the southern part of the esker, appear as prograding foresets which grade southward into deep-water sands. More common are subaqueous fans ranging in size from a few square hectares to tens of square kilometres. Morphologically these fans vary from flat-topped, near level surfaced, to hummocky, kettled terrain. Proximal sediments consist of trough cross-stratified deposits grading into rippled sands and then to more distal parallel-bedded sands. This facies change is marked by a fining of the sediments with gravelly layers being confined to the near-ice environment.

Pebble counts, heavy mineral suites, and geochemistry suggest differing provenances and processes of deposition for the various esker sedimentary environments. Sediments in the crest are derived from two main zones within the ice: 1) subglacially transported debris carried in the base of the glacier, and 2) englacially and supraglacial transported material held in and on the ice mass.

The debris-rich basal ice flows toward the esker tunnel in response to differential pressure. Water flowing through the tunnel erodes the ice freeing the trapped sediments. Supraglacial material is washed down from the glacier surface into the esker conduit in a "karstic" drainage network. Preliminary estimates suggest that approximately 40 percent of the esker sediments may be derived in this manner. From a prospecting point of view the englacial and supraglacial sediments may be considered as having intermediate to distal sources and the subglacial material as having local sources. It must be noted, however, that after the rock fragments enter the esker they are subject to further transport making the term local, in this case, relative.

Ice-marginal deposits, including deltas, subaqueous fans, and the ice-walled channel environment, present along the Munro Esker, have different processes active during deposition. Two material sources exist: 1) "sheared-up" sediments originating from just behind the ice front, and 2) supraglacial sediments carried off the glacier by streams and slumps. Transport distances beyond the ice are limited, except where reworking of deposits by wave action took place during regression of the glacial lake.

Kimberlite Float

During the course of the 1981 field season a fist-sized piece of kimberlite, weighing approximately 1 kg was found in the Munro Esker. The rock was discovered in a gravel pit south of Highway 66 in Gauthier Township, 300 m west of the Esker Lakes Provincial Park Road. The pit is operated by Nelson Brothers Construction Company Limited of Kirkland Lake and is active on demand. The pit was revisited in 1982 with G. Grabowski, Resource Geologist, Kirkland Lake, and a boulder of kimberlite weighting 11.6 kg was uncovered.

In hand specimen, the first find is yellowish grey containing abundant altered olivine grains (<4 mm), and crustal microxenoliths, <3 mm in size. Altered peridotite fragments and discoidal shaped garnet megacrysts are also visible.

Thin section analysis by J.v.A. Robey, Kimberley Petrographic Unit, Kimberley, South Africa, has determined the coarse constitutents of the rock to be:

1. olivine phenocrysts commonly between 0.10 and 0.35 mm but up to 1.5 mm; all grains are totally serpentinized with most having phlogopitized rims and some displaying carbonate replacement of serpentine
2. olivine megacrysts, 0.7 to 4 mm, which are altered to serpentine, carbonate, and occasionally clay minerals
3. crustal microxenoliths, up to 3.5 mm in size, consisting of a mass of fine-grained calcite, clay, and opaque minerals
4. ultra-basic microxenoliths
5. clinopyroxene megacrysts

The matrix of the kimberlite was found to consist of:

1. serpentine which is primary and forms the cementing interstitial material to all other matrix constituents
2. diopside tablets up to 0.08 mm (approximately 5:1 length to width ratio) and smaller microlites that crowd the matrix serpentine and are concentrated around pelletal lapilli
3. magnetite which is scattered throughout the serpentine matrix
4. perovskite which occurs as yellow, cubic euhedra, 0.02 to 0.05 mm, commonly nucleated about a magnetite grain

A distinctive textural feature of this rock is the presence of abundant pelletal lapilli. The pelletal lapilli are rounded, often spherical segregations of kimberlitic material set in the matrix. These segregations consist most commonly of accretionary kimberlitic material surrounding core crystals or fragments that could be any of the coarser constituents of the rock. The rock has been classified as a tuffaceous kimberlite (breccia).

The hand specimen of the second, larger kimberlite boulder is also a yellowish grey with numerous crustal macroxenliths. Altered olivine grains are abundant as are grains of chrome diopside and high magnesium ilmenite. Petrographic examination of the specimen is currently in progress.

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No. S14 Quaternary Geology of the Sydenham, Bath, and Yorkshire Island Areas, Lennox and Addington, Frontenac, and Prince Edward Counties, Southern Ontario

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THIS PROJECT WAS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUDSIDIARY AGREEMENT.

Introduction

The mapping of surfical deposits in the Sydenham (31 C/7), Bath (31 C/2), and Yorkshire Island (30 N/15) areas, at a scale of 1:50 000, was completed during the 1982 field season. This area is situated along the northeastern shore of Lake Ontario extending northward to Latitude 44°30′N, and between Longitudes 76°30′W and 77°00′W.

This area was previously included in a regional physiographic study of Southern Ontario by Chapman and Putnam (1966) and later was mapped by Mirynech (1978) for the Geological Survey of Canada. The purpose of the present mapping is to update previous studies and provide a more up-to-date database consistent with similar studies being carried out in Ontario.

Bedrock

The bedrock of this area was described by Liberty (1971) and later updated by Carson (1981, 1982). Precambrian

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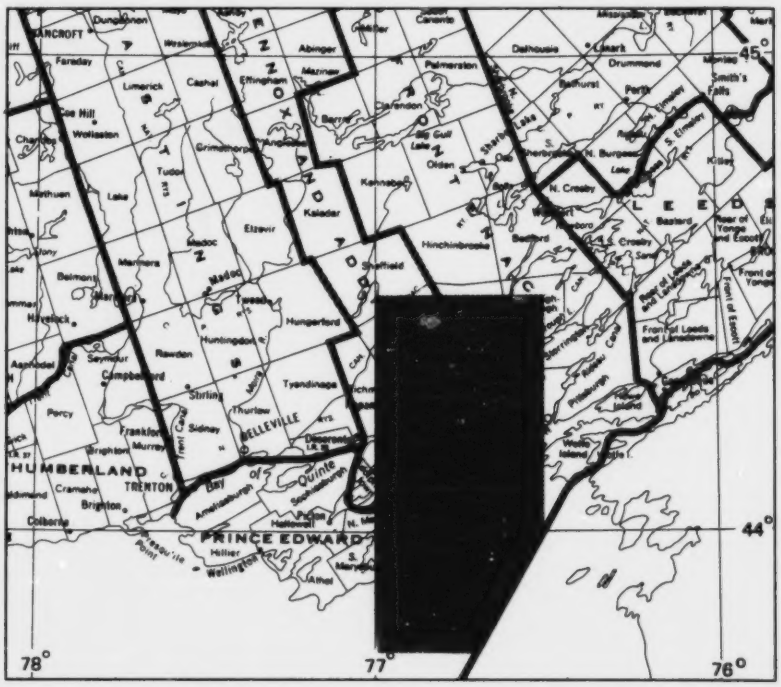

LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

bedrock, primarily of granitic composition, is present in the northern part of the Sydenham map sheet. The major part of this map-area is underlain by Simcoe Group Limestone with some shale (Middle Ordovician age). Arkosic sandstone, siltstone, and shale of the Shadow Lake Formation is commonly observed underlying the younger limestones. Subsurface data indicate that the Precambrian basement rocks beneath this area consist of metasediments and metavolcanics of the Grenville Province. Small outliers of the Potsdam Sandstone (Cambrian age) have been noted along the southwestern shore of Knowlton Lake and north of Halleford.

Physiography

This area has been subdivided into 3 physiographic regions: the Dummer Moraines, the Napanee Plain, and the Prince Edward Peninsula by Chapman and Putnam (1966). Because of the thin drift cover, the underlying bedrock provides much of the topographic control. The most notable topographic features over much of the map-area are:

1. extensive, flat limestone plains thinly veneered by lacustrine clay
2. prominent north-facing Paleozoic bedrock escarpments
3. a drumlinized till plain

In the central and northwestern part of the Sydenham map sheet an extensive area of hummocky topography, Dummer Moraine, predominates.

Quaternary Geology

The oldest glacial sediment in the map-area is a moderately stony silty sand to sandy silt till. This deposit directly overlies the bedrock surface but in many places has subsequently been removed by erosion or is covered by younger lacustrine deposits. This till can be several metres thick in local drumlin and drumlinoid landforms but typically is less than a metre thick over most of the map-area.

Sediments within the hummocky region in the north Dummer Moraines are typically composed of angular fragments of local Paleozoic bedrock sometimes supported by a loose variably sorted matrix of sand. These till-like deposits interfinger and/or grade into the till mentioned above, or poorly sorted fluvial gravels along the southern margin of this hummocky topographic zone. The origin of this deposit is still poorly understood but was most likely emplaced during stagnation of the last glacier by englacial and supraglacial debris derived from the melting glacial ice.

Small ice-contact deposits are found within this area. The most notable is an esker complex south of Tamworth. Outwash sands are common in the northwestern part of the Sydenham map-area.

Lacustrine deposits of silt and clay are widespread within bedrock valleys and other topographic lows. Large areas of bedrock plain are commonly covered by a thin veneer of lacustrine clay. Bedrock valleys, especially along the Napanee River and Wilton Creek, contain thick accumulations of lacustrine clay overlying ice-contact and outwash sand and gravel.

Raised beach deposits are present sporadically from place to place in the southern part of this area. They represent brief periods of ponding during the drainage of glacial Lake Iroquois.

Bedrock striations and grooves, plus the orientation of drumlin landforms, indicate a glacial ice flow of 210° to 220° over much of the northern and eastern parts of this area. This ice flow direcion gradually changes to between 240° and 260° in the southwestern part. Cross-cutting striae observed in the extreme southern part of this area indicate a minor, late readvance of the ice from the southwest at 290° to 300°.

Economic Geology

Sand and gravel is extracted from the many small ice-contact, outwash, and raised beach deposits found in the area. Most pits in this area are either abandoned or are active on demand.

Several abandoned quarries are present in the map-area. Canada Cement Lafarge Limited is presently quarrying limestone near Bath for use in the manufacture of cement.

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No. S15 The Stratigraphic Significance of the Dummer Moraine, Bannockburn (31 C/12) and Surrounding Areas

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THIS PROJECT WAS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

Quaternary mapping of the Bannockburn map-area (NTS 31 C/12), initiated by Goldstein (1981), was continued by the author in 1982, together with a more detailed study of the Dummer Moraine. The latter study is the subject of this summary.

Studies concerning the origin and significance of the Dummer Moraine have been made in recent years (Schluchter 1979; Gadd 1980). However, the stratigraphic relationship between the Dummer Moraine and other glacial deposits has received little attention. This study therefore emphasizes the stratigraphic significance of the Dummer Moraine.

The Dummer Moraine constitutes an area of irregular, very stony topography bordering the southern limit of the Canadian Shield. It extends eastward from the Kawartha Lakes and disappears just east of Tamworth in Lennox and Addington County (Chapman and Putnam 1966, p.313). Material with physical characteristics similar to that found within the Dummer Moraine has been seen as far west as 5 km east of Dalrymple Lake in the Orillia map-area. The Dummer Moraine may therefore span a distance of approximately 160 km from east to west, and be more than 20 km wide in places.

The Bannockburn map-area (NTS 31 C/12) which is bounded by Latitudes 44°30′N and 44°45′N, and Longitudes 77°30′W and 78°00′W includes part of the Dummer Moraine. Selected stratigraphic sites outside the Bannockburn map-area were examined to further assist the present study.

General Geology

The Dummer Moraine characteristically exhibits a very hummocky topography with relief seldom exceeding 6 m.

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LOCATION MAP Scale: 1: 1 584 000 or 1 inch to 25 miles

It is this distinctive topography of the Dummer Moraine which has led several investigators to describe it as an ice-stagnation feature.

The "Dummer till" (an informal name, here applied to material commonly found within the Dummer Moraine) typically is compact and extremely stony. Clasts are dominantly angular in shape and range in size from pebbles to large boulders. The dominant clast lithology strongly reflects the underlying Paleozoic bedrock. The Precambrian clast content is usually less than 2 percent. The matrix of the "Dummer till" is usually sandy, although a silty clay matrix was noted in a few localities. The finer matrix is attributed to the shaly interbeds of certain Ordovician strata locally underlying the Dummer Moraine (e.g. Verulam Formation).

Another type of material, also found within the Dummer Moraine, is in contrast quite distinct from the "Dummer till" described above. In this other material the clasts are less abundant, better rounded, and include a much greater percentage of Precambrian material than is found in the "Dummer till". Striated and faceted clasts are common. This other material, considered to be a lodgement till, commonly occurs in drumlins, drumlinoid ridges, and in ground moraine. In Verulam Township, and elsewhere, some of the terrain underlain by this lodgement till has a hummocky appearance.

Stratigraphy

At several exposures within the Dummer Moraine (as defined by Chapman and Putnam 1966) the lodgement till is seen to be overlying "Dummer till". The contact is usually quite sharp, and in at least 2 localities stringers of lodgement till appear to have been squeezed into the underlying "Dummer till". Only two exposures of "Dummer till" overlying lodgement till were observed by the author. The contact between the two is again sharp. However, the matrix of "Dummer till" at these 2 locations is, unusually, very loose. In one locality, an inclusion of "Dummer till" was found within lodgement till which was in turn overlain by "Dummer till". In some instances, the "Dummer till" is difficult to distinguish from lodgement till.

All of the above relationships suggest that "Dummer till" and lodgement till are facies of one another.

The fact that lodgement till overlies "Dummer till" suggests that both were deposited subglacially by active ice. This assumes that the "Dummer till" identified above and below the lodgement till is the same and that the lodgement till was deposited by subglacially active ice.

Discussion

Early investigators believed that "Dummer till" was morainic in origin because the topography is hummocky and the till itself texturally resembles ablation drift. Two questions that must therefore be answered are: 1) why is the topography hummocky? and 2) why is the till so coarse?

The hummocky nature of the topography may be the result of the following factors:

1. glaciofluvial and fluvial erosion (dissection)
2. the relative erodability of the limestone bedrock
3. an irregular ice-bedrock interface perhaps influenced by the Precambrian Shield

The first two factors appear to be the most likely mechanisms. Strong dissection has been noticed on both varieties of till. However, under such circumstances a strong boulder lag would be expected, and it is in some instances lacking. Preferential erosion of the Paleozoic bedrock is believed to be the most likely factor. In places, the bedrock is highly fractured, jointed, and easily susceptible to glacial erosion. This may also explain why the till is so coarse. Glacial ice advancing over the Precambrian-Paleozoic bedrock contact probably became oversaturated with local Paleozoic debris and was unable to fragment it prior to deposition.

The "Dummer till" is therefore thought to be a coarse facies of lodgement till. In this way, it can occur either above or below the more typical lodgement till.

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No. S16 Paleozoic Geology of the Northern Part of the Ottawa-St. Lawrence Lowland, Southern Ontario

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THIS PROJECT WAS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

Geological mapping of the northern part of the Ottawa-St. Lawrence Lowland during the summer of 1982 was a continuation of the 1981 mapping program (Carson 1982) and involved the examination of the following map-areas: Westport (31 G/9), Perth (31 C/16), Carleton Place (31 F/1), Ottawa (31 G/5), Russell (31 G/6), Thurso (31 G/11), Alexandria (31 G/7), Hawkesbury (31 G/10), Huntingdon (31 G/1), Vaudreuil (31 G/8), and Lachute (31 G/9). Parts of Arnprior (31 F/8) and Quyon (31 F/9) were examined, and additional mapping was conducted in the Kemptville (31 G/4), Winchester (31 G/3), and Cornwall (31 G/2) map-areas. The report area is bounded by the Ottawa River and Latitude 44°30'N, and by Longitude 76°30'W and the Ontario-Quebec border.

The Paleozoic geology of the region has been the subject of previous studies by Wilson (1946), Wilson and Dugas (1961), Wilson, Brownell, and Wynne-Edwards (1967), Wilson, Liberty, and Reinhardt (1973), and Wilson, Kirwan, Livingstone, and Hill (1973). The advisability of remapping the geology of the region resulted from:

a) the need to revise the stratigraphic nomenclature of the rocks in the area (for example, subdivision of the Ottawa Formation lithostratigraphically rather than biostratigraphically)

b) the desirability to correct errors in previous mapping (for example, assignment of outcrops of March Formation sandstone to the Nepean Formation and of March Formation dolostone to the Oxford Formation)

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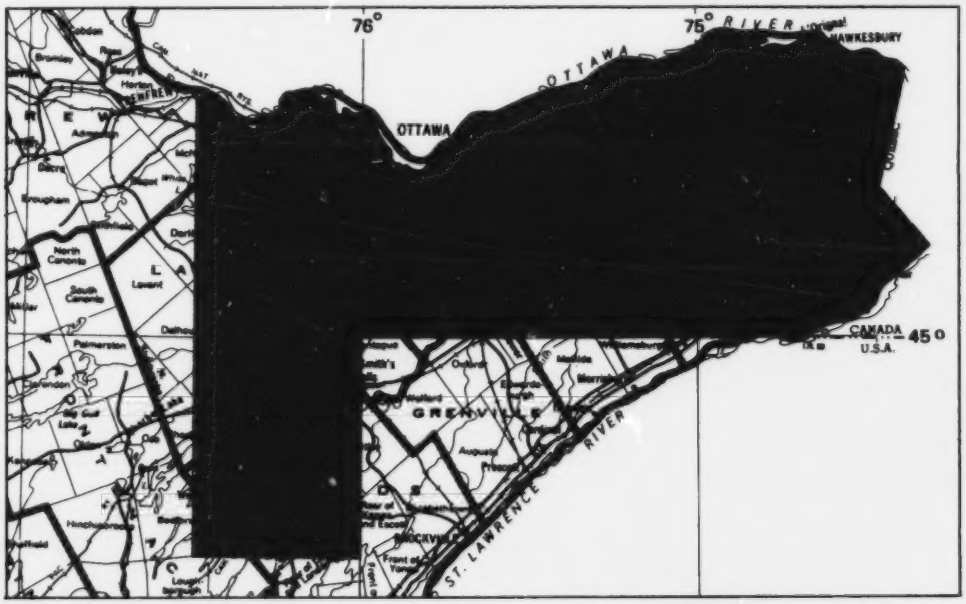

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

c) the availability of a large amount of surface exposure (roadcuts and quarries) and drillcore information which was not in existence at the time of previous studies

General Geology

The Paleozoic stratigraphy of the Ottawa-St. Lawrence Lowland is summarized in Table 1. Paleozoic bedrock outcrop is generally abundant in the western part of the region and within approximately 10 km of the Ottawa River, and consists of cliff and quarry sections and extensive areas of bedrock pavement. In the eastern part of the region, and more than approximately 10 km from the Ottawa River, a thick surficial sequence commonly overlies the bedrock and outcrop is generally sparse to moderate; scattered exposures occur in river valleys, and there are some areas of pavement (within which quarries have generally been developed). Excavation to a depth of up to 4 m for the natural gas pipeline of Trans Canada Pipelines Limited resulted in the availability of bedrock exposure along much of the pipeline route through the Arnprior, Ottawa, Kemptville, and Winchester map-areas.

Precambrian rocks outcrop to the west of the Lowland in the Westport, Perth, Carleton Place, and Arnprior map-areas, and Precambrian inliers are common in the western part of the Lowland. Precambrian rocks outcrop to the north of the Lowland in the Gatineau region of Quebec; a continuation of the Precambrian outcrop area to the south of the provincial boundary extends from Fitzroy Harbour to Kanata, and other continuations exist in the vicinities of Rockland and Lafaivre.

Unconformably overlying the Precambrian basement is the Potsdam Sandstone, subdivided in southern Quebec by Clark (1966, p.6) into the Covey Hill Formation and the overlying Cairnside Member of the Chateauguay Formation. The Nepean Formation (Wilson 1946, p.10) is correlative with the Cairnside Member, and it is proposed to introduce the term "Covey Hill Formation" to Ontario to refer to that part of the Potsdam Sandstone which underlies the Nepean Formation. The Covey Hill Formation consists of feldspathic quartz sandstone, commonly conglomeratic; the thickness decreases from several hundred metres in the eastern part of the Lowland (where it has been intersected in several drillholes) to zero in the western part (where only a few outcrops are known). The Nepean Formation consists of fine- to coarse-grained quartz sandstone, conglomeratic at the base, with a white to buff fresh surface and white to reddish brown weathered surface. Crossbedding is common.

The March Formation consists of interbedded quartz sandstone, sandy dolostone, and dolostone. The lower contact is the base of the lowermost dolomitic bed, and the upper contact is the top of the uppermost sandy bed.

The Oxford Formation consists of light to dark gray, sub-lithographic to fine crystalline dolostone. The weathered surface is light gray to buff to reddish brown. Stromatolites and calcite-filled vugs are common.

The Rockcliffe Formation consists of interbedded fine-grained light gray quartz sandstone and green shale. A basal conglomerate occurs locally. In the eastern part of the Lowland, interbeds of calcarenite (the St. Martin Member; Clark 1972, p.62) occur in the upper part of the Rockcliffe Formation.

The Ottawa Formation outcrops to the east of the Frontenac Axis and is correlative with the Simcoe Group, which outcrops to the west of the Axis. Previous subdivision of the Ottawa Formation has been based on biostratigraphy, and is as follows (from base to top) (Wilson 1946, p.24-25): Pamelia, Lowville, and Leray (Black River); and Rockland, Hull, Sherman Fall, and Cobourg (Trenton). The Ottawa Formation is divisible into six mappable lithostratigraphic units, consisting of the following (from base to top): a) interbedded silty dolostone, shale, and fine-grained calcareous quartz sandstone; b) interbedded lithographic to fine crystalline limestone and silty dolostone; c) lithographic to fine crystalline limestone; d) calcarenite and interbedded calcarenite, sub-lithographic to fine crystalline limestone, and shale; e) interbedded calcarenite, sub-lithographic to fine crystalline limestone, and shale; and f) nodular limestone. The distinction between Units D and E is based on the occurrence of calcarenite beds greater than 15 cm thick in Unit D. A detailed study would probably result in the determination of additional subdivisions of the Ottawa Formation (particularly of Units D and E).

The Eastview Formation consists of interbedded limestone and shale, and the Billings Formation of black shale. The Carlsbad and Russell Formations both consist of interbedded gray to greenish gray calcareous siltstone, shale, and limestone, and the Queenston Forma-

TABLE 1 PALEOZOIC STRATIGRAPHY OF THE OTTAWA-ST. LAWRENCE LOWLAND, SOUTHERN ONTARIO

Upper Ordovician	Queenston Formation Carlsbad and Russell Formations Billings Formation Eastview Formation
Middle Ordovician	Ottawa Formation Unit F Unit E Unit D Unit C Unit B Unit A Rockcliffe Formation
Lower Ordovician	Oxford Formation March Formation Nepean Formation
Cambrian	Covey Hill Formation
	UNCONFORMITY
Precambrian	Undifferentiated metamorphic and igneous rocks

tion consists of red siltstone. The Eastview and Billings Formations are correlative with the Whitby Formation, and the Carlsbad and Russell Formations with the Georgian Bay Formation. It is considered that there is insufficient lithological difference between the Carlsbad and Russell Formations for them to be considered as separately mappable units.

Three carbonatite dikes, striking generally east, and up to 40 cm thick, are exposed in the Francon Quarry at Blackburn. The dikes are probably of Cretaceous age (Bolton and Liberty 1972, p.21-22).

Structural Geology

Steeply dipping normal faults and fault zones with up to 800 m vertical displacement, and striking east to southeast, are commonly exposed. Bedding, normally close to horizontal, often dips steeply adjacent to faults and within fault zones. The fault system is characterized by branching of faults.

The fault system as determined by this study represents a major revision of previously published work. This has been made possible by an increased knowledge of the distribution and thickness of stratigraphic units, and by an increased amount of exposure of faults and fault zones in roadcuts and quarries. In addition, fault interpretation has been aided by use of the assumption that fault blocks have not been rotated, implying constancy of displacement along the length of each fault and constancy of the sum of the displacements across each fault junction.

Adams (in press) has described stress-relief buckles occurring in the McFarland Quarry, Ottawa, and a pop-up occurring in the nearby Dibblee Quarry. Quarry-floor buckles also occur in the quarries of the Cornwall Gravel Company (at Cornwall) and the Warren Paving and Material Group (8 km north of Cornwall).

Economic Geology

The March, Oxford, and Ottawa Formations are currently being quarried at many localities for use as crushed stone. Many of the quarries are described by Hewitt and Vos (1972).

The Queenston Formation is quarried near Russell for use in brickmaking by Domtar Construction Materials Limited. The operation is described by Guillet (1967, p.76-78).

The Nepean Formation is a potential source of silica for use in the glass and foundry industries (Powell and Klugman 1979), and the Billings Formation is being investigated as potential source of oil shale (see Johnson, this volume).

Post-Ordovician calcite-fluorite-barite-celestite-galena-sphalerite-chalcopyrite veins occur in the region. The veins strike east to southeast, and are up to 7 m thick. Faults (particularly fault junctions) are an important control for vein localization.

Copper-uranium mineralization (chalcopyrite-thucolite) occurs in the March Formation in the vicinity of South March (Charbonneau, Jonasson, and Ford 1975).

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No. S17 Oil Shale Assessment Project

M.D. Johnson[1]

THIS PROJECT WAS PART OF THE HYDROCARBON ENERGY RESOURCES PROGRAM (HERP), AND IS FUNDED BY THE MINISTRY OF TREASURY AND ECONOMICS UNDER THE BOARD OF INDUSTRIAL LEADERSHIP AND DEVELOPMENT (BILD) PROGRAM.

Introduction

The Oil Shale Assessment Project is aimed at a preliminary evaluation of the resource potential of Ontario's Paleozoic black shale units. These include the Whitby, Billings, Marcellus, and Kettle Point Formations. Although these shales subcrop extensively in Southern Ontario (Figure 1), they are only poorly known from small surface exposures and limited subsurface information.

The initial examination suggests that 3 of the Paleozoic shale units have a sufficiently high hydrocarbon content to warrant further study, the lower member (the Craigleith Member) of the Ordovician Whitby Formation (often referred to as the Collingwood shale; Liberty 1969), and the Devonian Marcellus and Kettle Point Formations. Thus far, investigation has been made of the Whitby Formation and equivalent Billings Formation only. Study of the Devonian units will begin late in 1982.

The database for the analysis of the Collingwood shale was developed from the field investigation of surface exposures, combined with geological and organic geochemical study of drillcores taken from 22 localities (Table 1).

Location

Potential oil shale deposits of Ordovician age in the Great Lakes-St. Lawrence Lowlands are all found south of Latitude 46°N. These rocks are located near the surface around Ottawa (Billings Formation), and in the belt trending from northern Manitoulin Island, under Georgian Bay, to the Collingwood area (hence the name of the unit), and southeast into the Toronto-Pickering area. In the subsurface, this unit is found throughout Ontario, southwest of the outcrop belt. It dips regionally to the southwest, and is about 1000 m below the surface in Essex County.

Potential oil shale strata of Devonian age subcrop around Sarnia, Chatham (Kettle Point Formation), and Port Stanley (Marcellus Formation) (Figure 1). Only outcrops of the Ordovician shales were visited in 1982.

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Field Study

The Collingwood shale has been sampled and studied at 50 localities. These sites occur around Pickering, Toronto, Collingwood, and on Manitoulin Island. Field study of the lithologically (and stratigraphically) equivalent Billings Formation in the Ottawa area was not attempted due to limited exposure and poor hydrocarbon generating potential, as suggested by a preliminary organic geochemical study made of Billings' subsurface samples.

Specifically studied in the field analyses were features which would permit correlation of outcrop and core samples.

General Geology

The Whitby Formation rests on the Middle Ordovician Lindsay Formation. The Whitby consists of grey, brown, and black shales. This formation has a maximum thickness in Ontario of about 60 m (Brigham 1972), and is composed of 3 members of which only the lowest (the Collingwood shale) has a sufficiently high organic carbon content to be considered a potential oil shale. The contacts between the 3 members of the Whitby are gradational making member distinction difficult.

The lowest member is normally distinguished by its black colour, calcareous nature, and high fossil content, coincident with a pronounced petroliferous odour. The 1982 study suggests that the Collingwood shale is 7 m or less in thickness and is thinner in the central part of the subcrop belt. The Whitby Formation directly overlies the grey mottled and fossiliferous limestones of the Lindsay Formation.

The upper contact of the Whitby Formation with the overlying Georgian Bay Formation is marked by the first appearance of dolostone interbeds. Surface exposures of the Collingwood shales are mostly located near Craigleith on Georgian Bay, as a series of relict shoreline erosional features and stream cuts.

Drilling of Ordovician Strata

During the winter and spring of 1982, 20 diamond-drill cores of these Ordovician shale units were obtained (Ta-

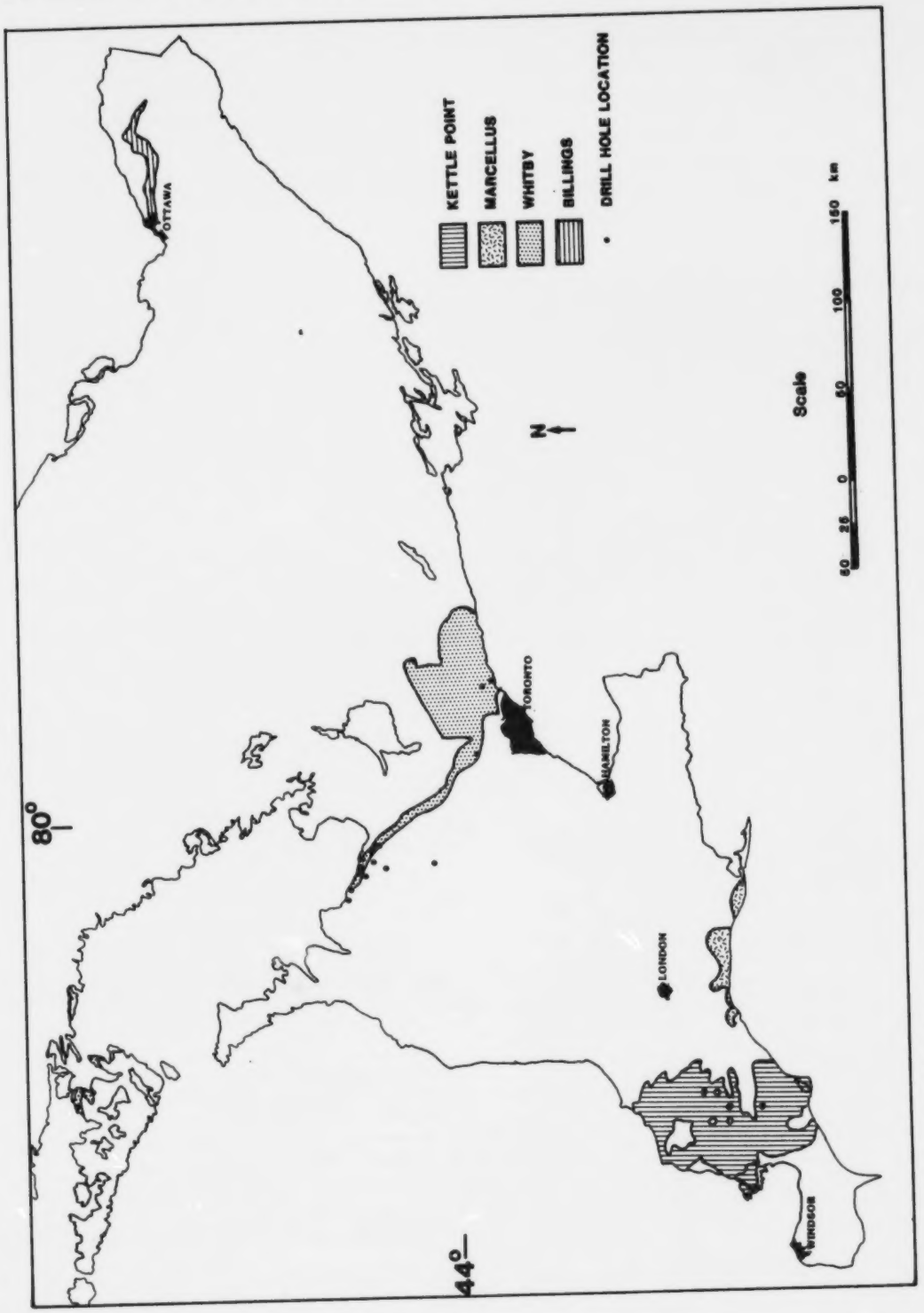

Figure 1—Oil shale formations in Ontario.

ble 1). Of these, 2 were from the Billings Formation, and 18 from the Whitby Formation. Two additional cores (not intersecting the Collingwood shale) were taken in the Collingwood area to assist in regional stratigraphic correlations. Included in this program was the coring of one deep hole to the Precambrian basement. This was located west of the subcrop belt to determine the nature of the shales at depth and assist in regional correlations.

Most of the holes were geophysically logged prior to plugging. Core recovery was good with 1550 m being returned. Geological descriptions and the geophysical logs for each core are being released in Open File Reports.

Drilling of Devonian Strata

During the fall of 1982, the study of Devonian potential oil shale strata will begin with the drilling of 25 shallow holes to sample subcrop formations, and 4 deep holes to the Precambrian basement. Of the shallow cores, 20 will be drilled in the Kettle Point Formation, and 5 will sample the Marcellus Formation. Overburden sampling will also be carried out to complement Quaternary geological mapping in the region. Lithological descriptions, geophysical logs, and hydrocarbon analyses of the core will be released in future Open File Reports.

TABLE 1 SUMMARY OF ORDOVICIAN OIL SHALE ASSESSMENT DRILLING

HOLE NUMBER	LOCATION		FORMATIONS	TOTAL DEPTH OF DRILLING
	COUNTY	LOT AND CONCESSION		
Nobleton 1	Regional Munic. of York	King Tp. Lot 21-22, Conc. V	Whitby/Lindsay	250.24 m
SIS 1	Munic. of Metropolitan Toronto	Borough of Scarborough Rouge Creek Park	Whitby/Lindsay	56.01 m
SIS 2	Reg. Munic. of Durham	Town of Ajax Lot 16, Conc. II	Whitby/Lindsay	32.62 m
SIS 3	Reg. Munic. of Durham	Town of Ajax Lot 32, Range II	Whitby/Lindsay	42.52 m
SIS 4	Munic. of Metropolitan Toronto	City of Toronto Don Valley Brickyard	Georgian Bay/Whitby/Lindsay	124.97 m
SIS 5	Manitoulin District	Howland Tp. Lot 16, Conc. VI	Whitby/Lindsay	38.10 m
SIS 6	Manitoulin District	Sheguiandah Tp. Lot 27, Conc. X	Georgian Bay/Whitby/Lindsay	49.30 m
SIS 7	Manitoulin District	Howland Tp. Lot 23, Conc. VI	Whitby/Lindsay	27.43 m
SIS 9	Simcoe Co.	Nottawasaga Tp. Lot 23, Conc. VII	Carlsbad/Billings	98.15 m
SIS 10	Reg. Munic. of Ottawa-Carleton	Cumberland Tp. Lot 15, Conc. V	Billings/Eastview	51.82 m
SIS 13	Grey Co.	Collingwood Tp. Lot 9, Conc. V	Lockport/Reynales/Cabot Head/Manitoulin/ Whirlpool/Queenston	75.64 m
SIS 14	Grey Co.	Collingwood Tp. Lot 5, Conc. VI	Lockport/Fossil Hill/Cabot Head	35.97 m
CLGD 1	Grey Co.	Collingwood Tp. Lot 27, Conc. VII	Whitby/Lindsay	63.70 m
CLGD 2	Grey Co.	Collingwood Tp. Lot 24, Conc. VIII	Georgian Bay/Whitby/Lindsay	117.34 m
CLGD 3	Grey Co.	Collingwood Tp. Lot 26, Conc. VII	Whitby/Lindsay	57.63 m
CLGD 4	Grey Co.	Collingwood Tp. Lot 25, Conc. IV	Lindsay	32.08 m
CLGD 4b	Grey Co.	Collingwood Tp. Lot 25, Conc. IV	Whitby/Lindsay	55.90 m
CLGD 6b	Grey Co.	Collingwood Tp. Lot 16, Conc. II	Whitby/Lindsay	49.68 m
CLGD 7b	Grey Co.	Collingwood Tp. Lot 10, Conc. I	Whitby/Lindsay	80.01 m
CLGD 16	Grey Co.	Collingwood Tp. Lot 40, Conc. XII	Whitby/Lindsay	80.85 m
CLGD 17	Grey Co.	St. Vincent Tp. Town of Meaford	Whitby/Lindsay	54.96 m
Corbetton	Dufferin Co.	Melancthon Tp. Lot 251, Conc. II	Lockport/Cabot Head/ Manitoulin/Whirlpool/ Queenston/Georgian Bay/ Whitby/Lindsay/Verulam/ Bobcaygeon/Gull River/ Shadow Lake/ Precambrian	602.79 m

Hydrocarbon Analyses

Selected portions of the Ordovician drillcores were subjected to organic geochemical analysis, by J.F. Barker and assistants at the University of Waterloo. Tests performed on the core included total organic carbon, total inorganic carbon, kerogen hydrogen-carbon ratios, yield on pyrolysis, and the industry standard, the Fischer Assays. These results are being released in an Open File Report.

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No. S18 A Comparative Study of Some Peatlands of Northern Ontario: Preliminary Report

W. Shotyk[1] and P.G. Telford[2]

THIS PROJECT WAS PART OF THE HYDROCARBON ENERGY RESOURCES PROGRAM (HERP), AND WAS FUNDED BY THE MINISTRY OF TREASURY AND ECONOMICS UNDER THE BOARD OF INDUSTRIAL LEADERSHIP AND DEVELOPMENT (BILD) PROGRAM.

Introduction

Peat deposits in 3 areas of northern Ontario were investigated as part of the peat component of the Hydrocarbon Energy Resources Program (HERP). These areas are located northeast of Bruce Mines in Galbraith Township, northwest of Timmins in Aitken, Hicks, Moberly, Poulett, and Oke Townships, and along a transect from Timmins north to Moosonee.

The specific objectives of the work were different in all 3 areas. There were several secondary objectives including a comparative analysis of peat deposits in areas of differing bedrock and Quaternary geology, geographical setting, and climatic regime.

The peat deposit in Galbraith Township is in Dunns Valley, located approximately 24 km northeast of Bruce Mines. The deposit is accessible by road, and some preliminary peat evaluation work has been done previously at the site. This previous work was carried out by the Forest Resources staff of Northeastern Region, Ontario Ministry of Natural Resources, as part of an assessment of the development potential of the deposit. Development of the deposit, including drainage and clearing of vegetation, is now well underway. As part of the preliminary evaluation, some data concerning peat and water composition were produced. Thus the area was selected as a very convenient site to begin the peatland comparative study.

The peat deposits located approximately 60 km northwest of Timmins have been mapped recently by the Ontario Centre for Remote Sensing (OCRS), Ministry of Natural Resources, Toronto, using their Applicon mapping technique, with funding from HERP. The work in that area was carried out as part of the OCRS "ground-truthing" of their Applicon peatland map, also funded through HERP.

The geochemistry of peatlands investigated along the transect between Timmins and Moosonee may prove to be very interesting because of the significant changes in bedrock geology along the transect. The resource po-

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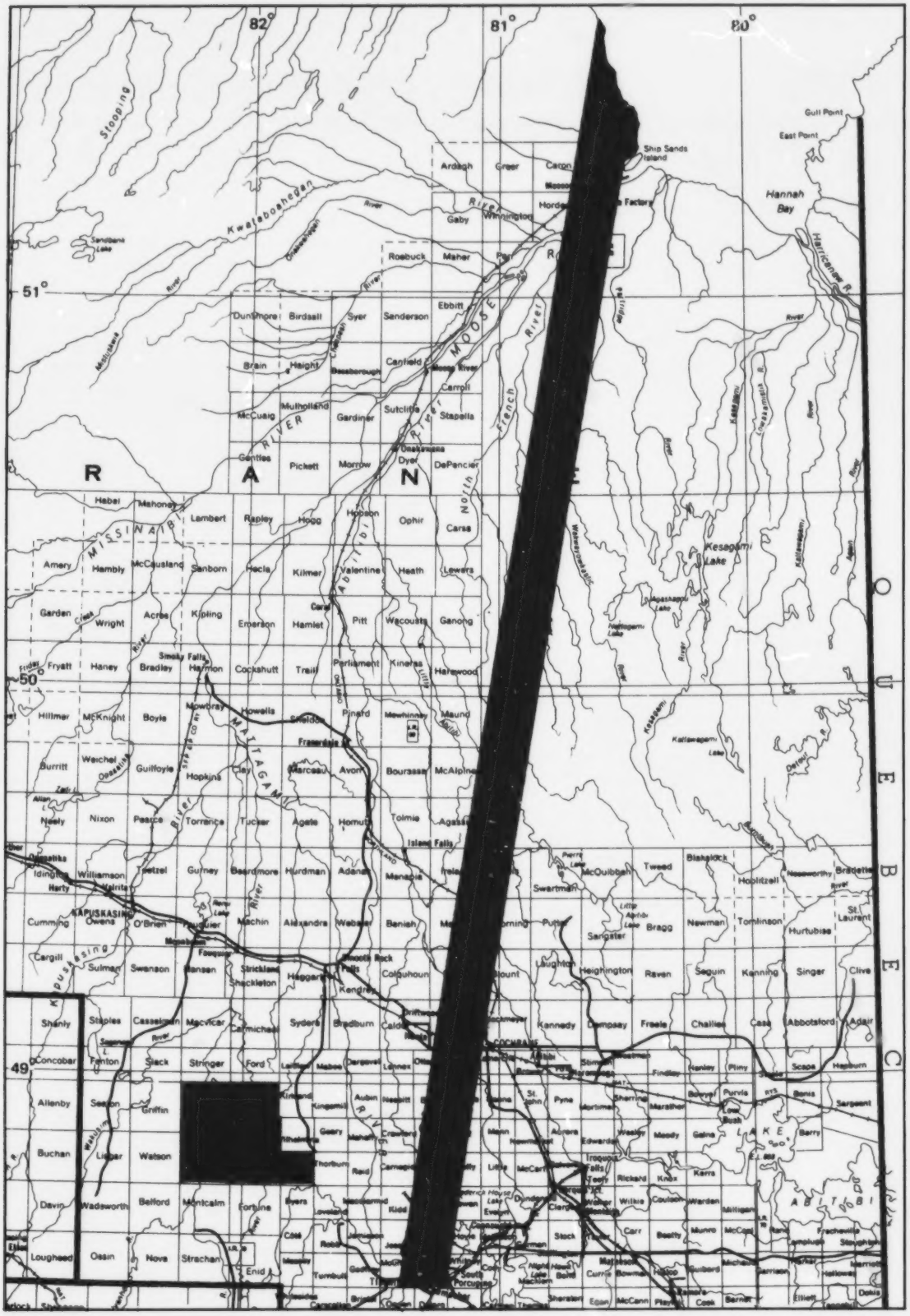
LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

tential of the deposits is also interesting because of the proximity of the deposits to relatively remote communities such as Moosonee.

Procedure

A detailed explanation of the field investigation procedure, including specific aspects of sample collection, will be released as part of a subsequent Open File Report. The following is an extract from this report.

All of the augers employed were of the modified Macaulay variety, either with 5 or 10 cm diameter sample chambers. Moss samples were collected by hand from hummocks and were typically *Sphagnum angustifolium, S. fuscum, S. magellanicum, S. rubellum*, or some combination thereof. Each layer of peat (the result of naturally occurring changes in peat type and degree of humification) was sampled individually. Where peat type and degree of humification did not change over a distance of more than 50 cm, the peat was sampled at 50 cm intervals. This permitted an analysis of the changes in peat chemistry (if any) with depth for a given peat type. This procedure was also applied to the collection of ooze samples. The basal sediment samples usually were obtained from not deeper than 50 cm below the basal peat (or ooze, if present) layer, except for one site at the Galbraith Deposit. At site L600N + 100W the clay was sampled almost every 50 cm over a distance of 5 m.

Galbraith Area

General Geology

The bedrock of the immediate area consists of rocks of the Gowganda Formation (conglomerate, arkose, quartzite, greywacke); copper mineralization is common throughout this formation (Giblin and Leahy 1967). Recent work by Giblin *et al.* (1979) shows that a fault may occur in the rock beneath the peat deposit. The direction of the fault can be visualized by connecting sites B00N and C1000N in Figure 1. Approximately 2.5 km west-southwest of the deposit there is additional copper mineralization at the boundary between the Mississagi Formation (quartzite, conglomerate, argillite) and Nipissing Diabase (diabase, quartz diabase, gabbro, diorite, granophyre). An abandoned gold mine (Havilah Gold Mining Company) is located in Nipissing Diabase approximately 5.5 km west-northwest of the peatland. This mine lies on a fault zone trending northwest through Madill and Aberdeen Lakes; a thin branch of the Nipissing Diabase runs northeast from the main body, and is faulted in several places approximately 1.5 km due north of the deposit. Uranium mineralization occurs approximately 9 km northwest of the peatland at the boundary between the Mississagi Formation and the Thessalon Formation (basalt, rhyolite, chert, quartzite). The Gowganda Formation is part of the Cobalt Group, while the Mississagi Formation is part of the Hough Lake Group; both of these groups are components of the Huronian Supergroup (2.5 to 2.16 Ga). The Nipisssing Diabase is post-Huronian (Robertson and Card 1972).

The peatland is flanked to the north and west by a ground moraine till with a moderate, undulating-rolling local relief (VanDine 1980). Immediately to the east of the deposit there exists a sandy silty glaciolacustrine plain with low local relief. Immediately to the north, west, and south of these surficial deposits, rock knobs of the Gowganda Formation protrude 85 to 135 m above the elevation of the peat deposit.

Peatland Description

The Galbraith Deposit is composed of 4 physiognomic groups: Conifer Swamp, Thicket Swamp, Meadow Marsh, and *Sphagnum* Bog (for detailed descriptions of each of these physiognomic groups the reader is referred to Jeglum *et al.* 1974).

The dominant vegetation in the Conifer Swamp is Black Spruce (*Picea mariana*), Tamarack (*Larix laricina*), and Labrador-tea (*Ledum groenlandicum*). In the Thicket Swamp the following occur: Red-Osier Dogwood (*Cornus stolonifera*), Speckled Alder (*Alnus rugosa*), and Willow (*Salix* sp.).

Most of the area of the peatland is *Sphagnum* Bog. The density of trees greater than 135 cm in height varies within the deposit; there are open, low density, medium density, and high density treed *Sphagnum* Bog zones. The following are common in these areas: Leather-leaf (*Chamaedaphne calyculata*), Labrador-tea (*Ledum groenlandicum*), Bog Rosemary (*Andromeda glaucophylla*), *Sphagnum magellanicum, Sphagnum fuscum, Carex oligosperma*, and *Eriophorum* sp.

Timmins Area

General Geology

Much of the following discussion is based on geological data from Thurston *et al.* 1976 and Pyke *et al.* 1973.

Early Precambrian felsic igneous and metamorphic rocks with ubiquitous north-oriented diabase dikes dominate the bedrock. In Aitken Township there are some pyroclastic rocks containing sulphide mineralization. The same is true of Moberly and Oke Townships. In Moberly Township there is an area of mafic pyroclastic rocks containing a relatively small zone of felsic metavolcanics and graphite. In Poulett Township there are some mafic-intermediate metavolcanics; within this unit a relatively small zone of metasediments (greywacke, arkose, quartzite) has been identified from diamond-drill core. The main peat deposits studied are 15 to 25 km due west of polymetallic (gold, silver, copper, lead, zinc) base-metal bodies. The approximately 3 km wide band of mafic pyroclastic rocks extending westerly through the centre of the peatland area is considered to be of "medium to nigh" mineral potential (Springer 1977).

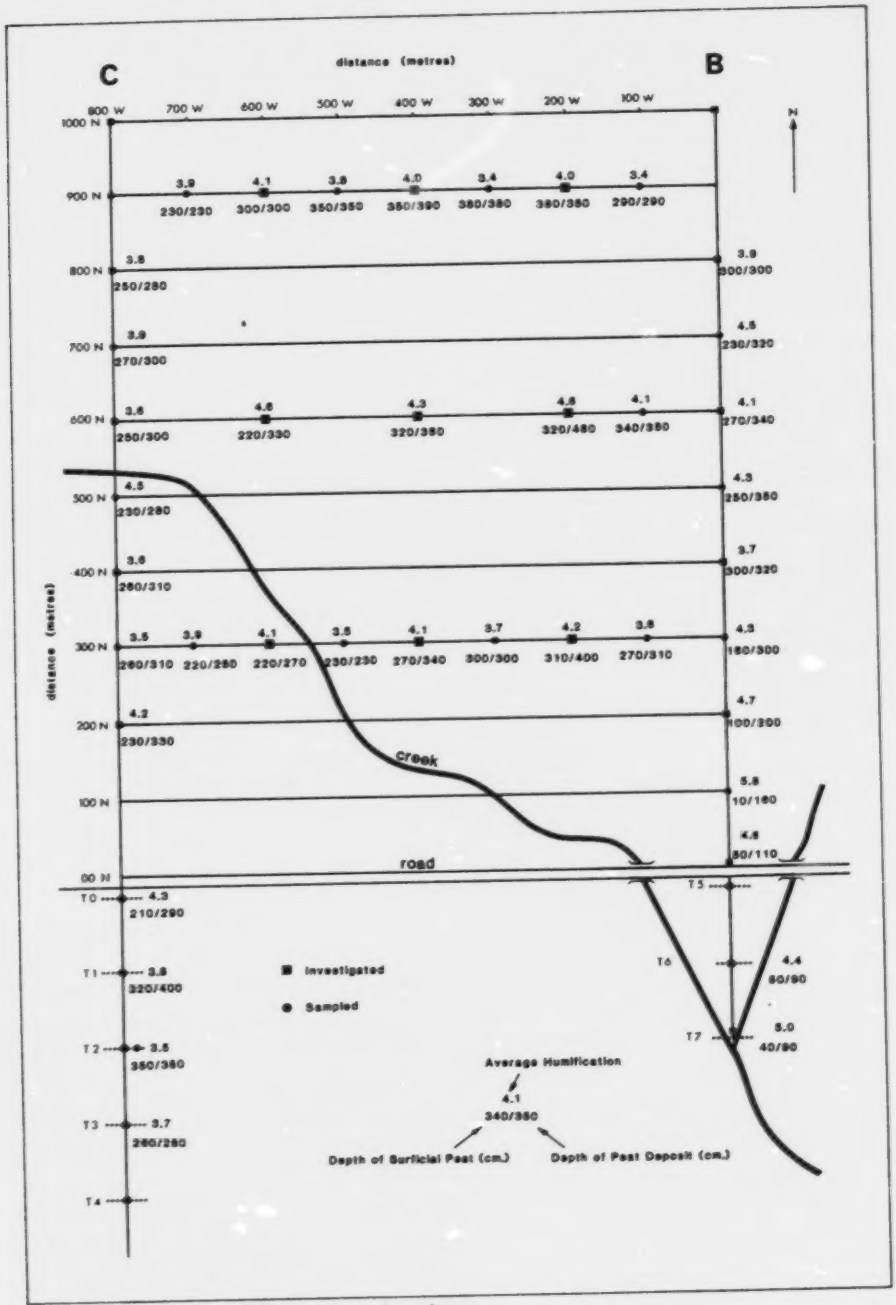


Figure 1—Galbraith peat Deposit site locations.

The surficial geology of the area is dominated by organic terrain (humic gleysols and fibrisols). There are bedrock knobs exposed in Hicks and Oke Townships. Sand and gravel esker segments are found in Hicks and Oke Townships also. Clayey ground moraine tills are important surficial features in Moberly and Oke Townships where they may be overlain by organic terrain. Many areas in the township of Aitken, and some in the township of Moberly, contain clayey silty lacustrine and glaciolacustrine plains. They may also be overlain by organic terrain (Lee 1979; Lee and Scott 1980).

Peat Description

Many different peatland types were encountered during this part of the project, for example: Graminoid, Low Shrub and Treed Fens; Thicket and Conifer Swamps; and *Sphagnum*, Graminoid, Low Shrub, and Treed Bogs. Typical plant species for each of these physiognomic groups are found in Jeglum *et al.* (1974).

Timmins-Moosonee Transect

General Geology

The exact location of each of the sample sites will be included in the Open File Report. Suffice to say here that JBL-1 to JBL-14 are found along an approximately straight line between Timmins and Moosonee, and the distance between sites is approximately 20 km. Sites JBL-15 and JBL-16 are in the James Bay Lowland east of the transect, along the Partridge River.

The bedrock changes significantly along the transect. These changes are summarized in Table 1. Underlying bedrock and that nearby the deposit have been described. In the "comments" section any nearby mineralization has been noted; also the appropriate reference has been provided.

Sado (1979) adequately described the surface of the Lowland as "one continuous swamp covered by a thick water-soaked blanket of mosses". As the name implies, the Lowland has very low relief with an average seaward gradient of 0.75 m per km. Glacial sediments are observed only along river valleys. The thickness of overburden on top of the sedimentary basin does not exceed 30 m. South of the Lowland basin the overburden covering the Precambrian rocks is thinner and less continuous.

Peatland Description

The many different peatland types encountered along the transect include Graminoid, Low Shrub, and Treed Fens; and Graminoid, Low Shrub, and *Sphagnum* Bogs. At 15 of the 16 sites common plant species were recorded on the Site Data records and will be included as an appendix in the subsequent Open File Report.

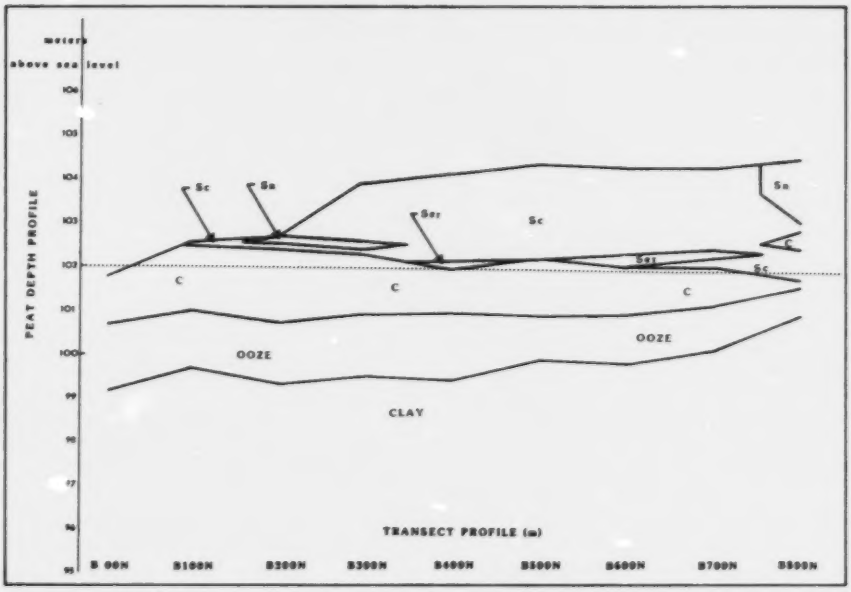


Figure 2—Peat and basal sediment type from B00N to B800N (C-carex; Sc - sphagnum with minor carex; Sn - sphagnum with minor shrubs; Ser - sphagnum with minor eriophorum).

TABLE 1 | **GENERAL GEOLOGY OF TIMMINS-MOOSONEE TRANSECT**

SITE	UNDERLYING BEDROCK	PROXIMAL BEDROCK	COMMENTS
JBL-1	–3 km wide of metasediments (greywacke, siltstone, argillite, slate)	–intermediate and mafic metavolcanics with sulphide mineralization surround the metasedimentary belt	–between the Timmins airport and the Mattagami River –near a major river fault –see Pyke *et al.* 1973
JBL-2	–felsic-mafic metavolcanics		–many Ag, Cu, Fe, Ni, Pb, and Zn occurrences found within a 6 km radius –see Pyke *et al.* 1973
JBL-3	–intermediate and mafic metavolcanics (mafic flows and pyroclastic rocks)		–3 km W of Cu, Zn mineralization –faults to the N, E, and S of the area –see Pyke *et al.* 1973
JBL-4	–migmatite-metasedimentary-metavolcanic complex	–5 km N of intermediate-mafic metavolcanics –1 km S of massive granitic rocks	–6 km N of an iron formation –see Bennett *et al.* 1968
JBL-5	–massive granitic rocks		–see Bennett *et al.* 1968
JBL-6	–massive granitic rocks		–see Bennett *et al.* 1968
JBL-7	–map unavailable?		
JBL-8	–migmatite-metasedimentary-metavolcanic complex		–see Bennett *et al.* 1968
JBL-9	–map unavailable?		
JBL-10	–3 km wide band of migmatite-metasedimentary-metavolcanic complex	–on either side of complex are felsic intrusive rocks (massive granitic pegmatites)	–see Bennett *et al.* 1968
JBL-11	–Kapuskasing granulite complex	–3 km W of migmatite metasedimentary-metavolcanic complex –5 km SW of intermediate metavolcanics with peripheral diabase dikes	–13 km NE of a magnetite occurrence –see Bennett *et al.* 1968
JBL-12	–Moose River Formation (limestone and dolomite, gypsum)	–Early Precambrian (Archean) felsic intrusive rocks and Kapuskasing granulite complex almost completely surround the relatively small basin of Moose River Formation	–5 km NE of gypsum occurrence –see Bennett *et al.* 1969
JBL-13	–Moose River Formation		–see Bennett *et al.* 1969
JBL-14	–Kwataboahegan Formation (brown bituminous fossiliferous limestone, minor chert)		–5 km S of the junction of the North French and Moose Rivers –see Bennett *et al.* 1969
JBL-15	–Sextant Formation (arkose, conglomerate, sandstone, shale, siltstone)	–6 km N of the Canadian Shield (Early Precambrian (Archean) felsic intrusive rocks)	–13 km S of the JBL-16, also along the Partridge River –see Bennett *et al.* 1969
JBL-16	–Kwataboahegan Formation	–11 km N of the Sextant Formation	–along the Partridge River –see Bennett *et al.* 1969

Results of the Study

The detailed results of site investigations in the Timmins area, and of sites along the Timmins-Moosonee transect will be found in the Site Data Records to be included in the Open File Report. All of the Site Data Records for the Galbraith Deposit will be included in the same Appendix. A brief discussion of some of the results obtained from the Galbraith study is given below.

Figure 1 is a map of that portion of the deposit which is currently being developed. The lines shown on the map represent lines which had already been cut through the vegetation on the peatland surface. The sites investigated were found on these lines; they were selected from sites already staked approximately 100 m apart. A stream is shown flowing southeasterly through the deposit; drainage ditches are not shown. For each site investigated, the average humification, surficial depth, and total peat depth are given.

The profile in Figure 2 represents the horizontal and vertical changes in peat type encountered along the line B00N to B800N. The peat deposit ends at approximately B950N (i.e. 950 m from the road along this line); this point corresponds to the base of the rock knob which rises approximately 85 m above the surface of the peat deposit. Notice that the clay underlying the deposit is almost level except for a slight rise near the base of the hill; the ooze between the peat and clay is also approximately level.

The profile illustrates a typical peatland succession (Moore and Bellamy 1974). The hydrological and vegetation character of the deposit has evolved through time. In the early stages of development the accumulation of carbonaceous material resulted from the deposition of allochthonous material and aquatic vegetation in a lake basin. Through time, continuous flowing, well aerated waters produced well humified peat. Continued peat growth affected the movement of water through the area. As a result of the steady accumulation of organic matter the peatland surface eventually rose above the old water level. Once this stage had been achieved, the nutrient status of the peatland changed from minerotrophic (well aerated, relatively high pH, and relatively high concentrations of plant-essential elements such as calcium, magnesium, and potassium) to ombrotrophic (poorly aerated, relatively low pH, and relatively low concentrations of calcium, magnesium, and potassium). As a direct result of the change in nutrient regime the plant population also changed; *Carex* species were replaced by *Sphagnum* mosses whose nutrient requirements are much less.

The ooze layer shown in Figure 2 consists of allochthonous materials and aquatic vegetation deposited in the earliest stage of the peatland's development. The *Carex* peat layer formed during the transition from the minerotrophic to ombrotrophic conditions. When Figures 2 and 3 are compared it is seen that the *Carex* peat layer of Figure 2 corresponds well to the H5-10 (i.e. well decomposed) peat layer of Figure 3. The *Sphagnum* layer, deposited under ombrotrophic conditions, closely corresponds to the H1-3 (i.e. poorly decomposed) peat. A peripheral observation is that one or all of the following affect the degree of humification of peat: oxygen status of peatland waters, (type? and) concentration of metals, pH, and peat type.

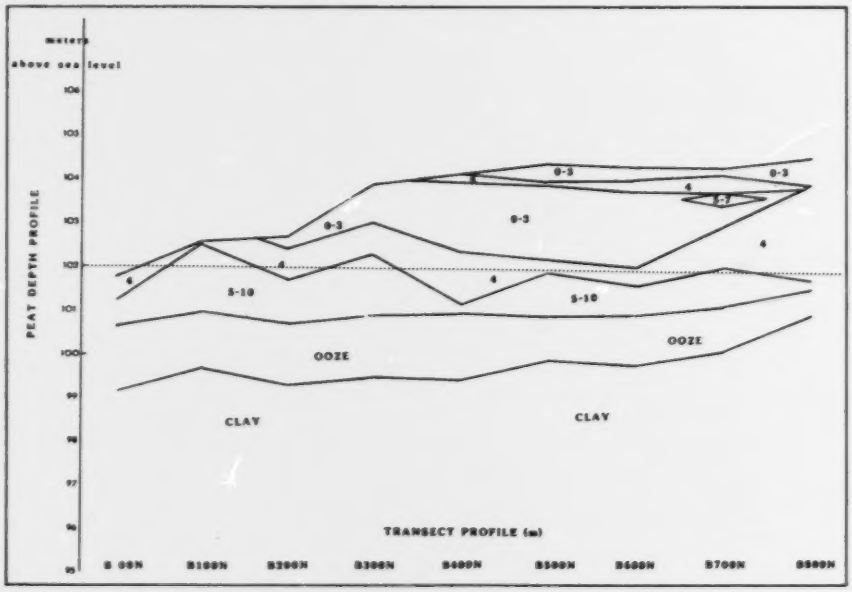


Figure 3—Degree of humification of peat (von Post scale) from B00N to B800N.

Analytical Program

A detailed discussion of the analytical program, including information regarding reference materials (the preparation of whole peat and peat ash reference material is currently underway in the Geoscience Laboratories, Ontario Geological Survey, Toronto), limits of detection, accuracy, and precision will be presented in the subsequent Open File Report. Only a very brief discussion of sample analysis is given below.

Peat deposits are well known accumulators of various elements. For example there is data available concerning anomalously high levels of fluorine (Yliruokanen 1976), nickel (Yliruokanen 1981), copper (Boyle 1977; Lett 1978; Yliruokanen 1981), zinc (Cannon 1955; Yliruokanen 1980b), arsenic (Minkkinen and Ylirůokanen 1978), gold (Boyle 1979), lead (Sapek 1976; Tanskanen 1977), and uranium (Armands 1967; Coker and DiLabio 1979; Yliruokanen 1980a). Thus analytical geochemistry is considered as an important aspect of peat evaluation.

Approximately 700 moss, peat, ooze, clay, sand, and rock samples have been collected from the various peatlands areas. Of this total, approximately 350 samples are being analyzed for Ag, As, Cd, Co, Cr, Cu, Fe, Pb, Mn, Ni, U, V, and Zn. Thirty samples from the Galbraith Deposit will be analyzed for all of the above and also Al, Au, B, Ba, Be, C, Ca, Cl, Cs, F, H, Hf, Hg, Ir, K, Li, Mg, N, Na, Nb, O (by difference), Os, P, Pd, Pt, Rb, Re, Rh, Ru, S, Sc, Si, Sr, Ta, Ti, W, Y, and Zr. Six samples from the Galbraith Deposit, including moss, peat, ooze, and clay, will be analyzed for all of the above and also Bi, Br, Ce, Dy, Er, Eu, Ga, Gd, Ge, Ho, I, In, La, Lu, Nd, Pr, Sb, Se, Sm, Sn, Tb, Te, Tl, Tm, and Yb (a total of 78 elements). The clay mineralogy and loss on ignition of basal sediment samples, and the calorific value of carbonaceous materials are also being investigated in selected samples from the Galbraith Deposit. The ash contents of all of the organic samples will be determined.

In addition to the peat samples from northern Ontario, peat samples were collected from each of the 3 peatland zones of New Brunswick (Keys *et al.* in press), and from the Holland Marsh north of Toronto. A peat sample from an Irish fuel peat bog has also been obtained. These samples will be analyzed for Ag, As, Cd, Co, Cr, Cu, Fe, Pb, Mn, Mo, Ni, U, V, and Zn. All of the raw data generated during this program will be released in the subsequent Open File Report.

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Geophysics/Geochemistry Programs

Geophysical, Geochemical, and Geochronological Surveys and Research, 1982

R.B. Barlow[1]

Geophysical Program

During the 1982 summer season, survey activity continued on the Night Hawk geophysical test range near Timmins, Ontario. In addition to the electromagnetic, gravity, and magnetic gradiometer surveys carried out by staff of the Geophysics/Geochemistry Section, researchers from the Geological Survey of Canada, the University of Toronto, Questor Surveys Limited, Aerodat Limited, and Geonics Limited have carried out experiments using airborne and ground electromagnetic, audiofrequency magnetotelluric, and seismic refraction and reflection techniques.

The gravity interpretation project was continued this year and was based on previous survey data covering the Cobalt Embayment-Grenville Front area. Eighteen Federal-Provincial aeromagnetic contour maps have been digitized and processed to aid interpretation of supercrustal intrusions and volcanic rocks in this area.

Several computer interpretation algorithms, including a 2½ D modelling routine, and an apparent density mapping routine, have been developed and used to interpret the residual Bouguer gravity anomalies after regional effects from deep-seated sources were removed.

A contract to test-fly a commercial aeromagnetic gradiometer system in 1983 has been awarded to Kenting Earth Sciences Limited. The project is funded equally by the Federal Department of Regional Economic Expansion (DREE) and the Ontario Ministry of Natural Resources under the Minerals Program of the Eastern Ontario Subsidiary Agreement. The vertical magnetic gradiometer system features a novel retractable boom assembly which is tail mounted on a Piper PA-31 Navajo aircraft. Two cesium vapour magnetometer sensing heads will have a separation of approximately 2 m in the survey mode, and the lower boom will retract for airport runway maneuvers. Currently, the development work has centred on the digital acquisition system and the construction of a lightweight self-orientating sensor assembly.

Geochemistry Program

Data obtained over a 3-year period, under the Kirkland Lake regional basal till project, are being computerized with the objective of producing multi-parameter, geochemical-trend maps for displaying down-ice dispersion trains in the lower till units, and combining this information with mineralogical data from the same horizon. Geological information, including regional structure, bedrock lithology, Quaternary geology, and airborne geophysical results, is being used to aid interpretation of the geochemical and mineralogical studies carried out over the previous 3-year period. This project is being funded equally by the Federal Department of Regional Economic Expansion (DREE) and the Ontario Ministry of Northern Affairs under the Community and Rural Resource Development Subsidiary Agreement.

Research in the Wawa area on acidic precipitation is continuing and now includes some 50 lakes where lake sediment cores have been subjected to limnological, palynological, and geochemical analysis. The objective of the research project is focused on de-

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veloping sampling, analysis, and interpretation techniques which can be applied to regional geochemical surveying projects in the future so as to maximize the utility of geochemical surveys for environmental as well as mineral potential evaluation.

Geochronology Program

Age dating projects in the North Trout Lake and Red Lake areas are approaching completion, and several new studies in the Southern Province have been initiated. Newly developed U-Pb zircon dating techniques now allow ages to be measured within a precision range of ±1 to ±3 Ma in most cases.

Staff of the Jack Satterly Geochronology Laboratory, Royal Ontario Museum, working with staff of the Ontario Geological Survey and of the University of Manitoba, have shown that a limited occurrence of foliated trondhjemite in the North Trout Lake area formed 2950 Ma ago, about the same time as a previously dated, nearby volcanic cycle. The metavolcanic belt also contains felsic units which were formed as late as 2720 Ma. This age correlates well with major late-phase plutonism in the region.

In the Red Lake area, dating produced evidence of time equivalent strata to the nearby Uchi metavolcanic belt dated previously and interpreted to have been formed between 2900 and 2740 Ma. Ten age dates produced recently from the area of the Red Lake belt containing these strata show cycles of volcanism ranging from 2990 to 2730 Ma.

In addition, age dates from 3 known regions of extensive alteration and gold mineralization in the Red Lake belt have ages which lie within the time span of the oldest volcanic cycle, 2890 to 2990 Ma. It has also been interpreted that gold was emplaced in the Dome Stock less than 2719 Ma.

Previous studies show that for metavolcanics in the Wabigoon Subprovince, approximately 250 km to the south, ages range between 2711 and 2745 Ma. Three post-orogenic intrusions have ages of 2695, 2698, and 2700 Ma. This study makes a major contribution to Early Precambrian geology because it demonstrates that volcanism, sub-volcanic plutonism, and diapiric upwelling of granitic rocks are part of the volcanic process.

No. 22 Night Hawk Geophysical Test Range Results, Night Hawk Lake, District of Cochrane

R.B. Barlow[1], D.H. Pitcher[2], and D.R. Wadge[3]

Introduction

During the summer field season, staff of the Geophysics/Geochemistry Section continued studies on a test range near Timmins, Ontario (Barlow 1981). The grid system, developed in 1981, covers an area of approximately 1 km^2 with north-trending lines 100 m apart, and stations 25 metres apart along the lines.

The test range program was initiated with the objective of developing certain areas, which are representative of exploration targets in Ontario, into sites for testing newly developed exploration technology. Sites that are selected for this purpose will be subject to ongoing tests using new geophysical equipment by Section staff and/or research scientists from university departments, industrial research and development groups, and staff scientists from the Geological Survey of Canada. The test ranges will therefore serve as field laboratories for geophysical research groups, thus aiding an important phase of exploration technology development. In addition, the sites will provide areas for instruction of field techniques in exploration geophysics.

To date, 3 ground electromagnetic systems have been applied using certain standard survey configurations in the time and frequency domain. Gravity and magnetic gradiometer data were also obtained this year.

In addition, tests have been carried out by staff of the Geological Survey of Canada and include seismic reflection, refraction, and electromagnetic techniques. Audiofrequency magnetotelluric (AMT) sounding tests have been carried out by graduate students at the University of Toronto Geology Department, and 2 airborne helicopter systems have been tested by Questor Surveys Limited and Aerodat Limited. A series of experiments have been carried out by Geonics Limited on a new concept in electromagnetic surveying.

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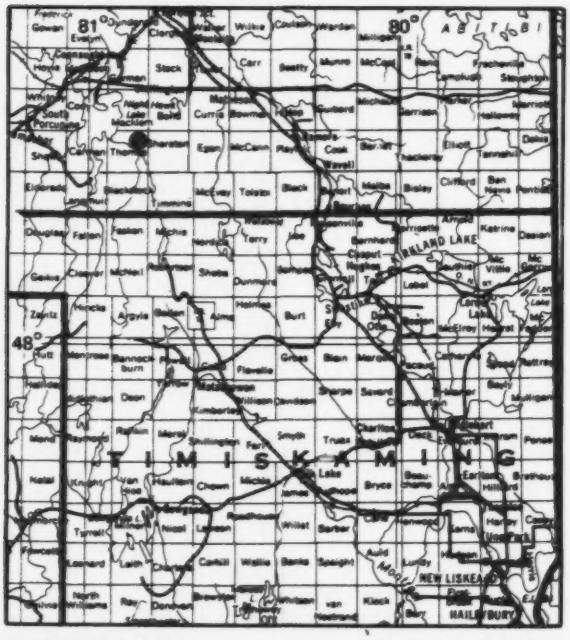

LOCATION MAP Scale: 1:1 584 000
or 1 inch to 25 miles

Location and Access

The test range is located in the northeastern quadrant of Thomas Township approximately 12 km south of Highway 101, on Gibson Lake Road. The Gibson Lake Road turnoff is located approximately 40 km east on Highway 101 from Timmins, Ontario.

A diagram (Figure 1) illustrating the grid, large transmitter loops, a previous drillhole, and access roads shows that few areas of the grid are without ready access by vehicle.

Survey Methodology

Gravity Data

In preparation for the gravity survey the 9 grid lines were levelled to an accuracy of 0.03 m from a bench mark established at 0+00, 0+00. The bench mark was tied to an existing permanent Ministry of Transportation and Com-

munications (MTC) bench mark on Highway 101 by several altimeter loops. The elevation of the grid bench mark was established as 298 m above sea level. Elevations on the grid range from a low of about 294 m to a high of about 303 m above sea level. A contour map of the grid is shown in Figure 2 using a contour interval of 0.5 m.

The gravity data were observed with a Lacoste-Romberg Model G gravity meter and were tied to control stations established by the Earth Physics Branch, Ottawa, at Timmins airport, the Ontario Northland Railway station in Timmins, and a station on Highway 101 near Night Hawk Lake. These stations form part of the National Gravity Network which is tied to the International Gravity Standardization Net 1971.

The observations were automatically gridded in the x and y directions using a computer algorithm with an interval of 25 m, and the relative Bouguer values were contoured using a 0.2 milligal contour interval.

The contours shown in Figure 3 illustrate the distribution of low density rocks, believed to be rhyolites and rhyolite breccia which form a trend in the westerly direction at the western end of the grid, and arcing to a northerly direction at the eastern end of the grid. Higher density rocks, presumably iron-rich tholeiites are evident on the southern and eastern sides of the grid.

Magnetic Gradiometer Data

The gradiometer data were observed with an EDA Model PPM-500 vertical magnetic gradiometer which records the total field at one sensor and the vertical gradient with 2 sensors separated by a 1 m distance. Contour maps of the total field and gradiometer data are presented in Figures 4 and 5, respectively, over the test range grid. The total magnetic field correlates well with the Bouguer gravity map, since both techniques presumably outline the zone of rhyolites and rhyolite breccia, which has a relatively low density as well as a relatively low magnetic susceptibility. The anomalously high magnetic and gradiometer readings to the south and east of the grid system are associated with the iron-rich tholeiites of relatively high magnetic susceptibility.

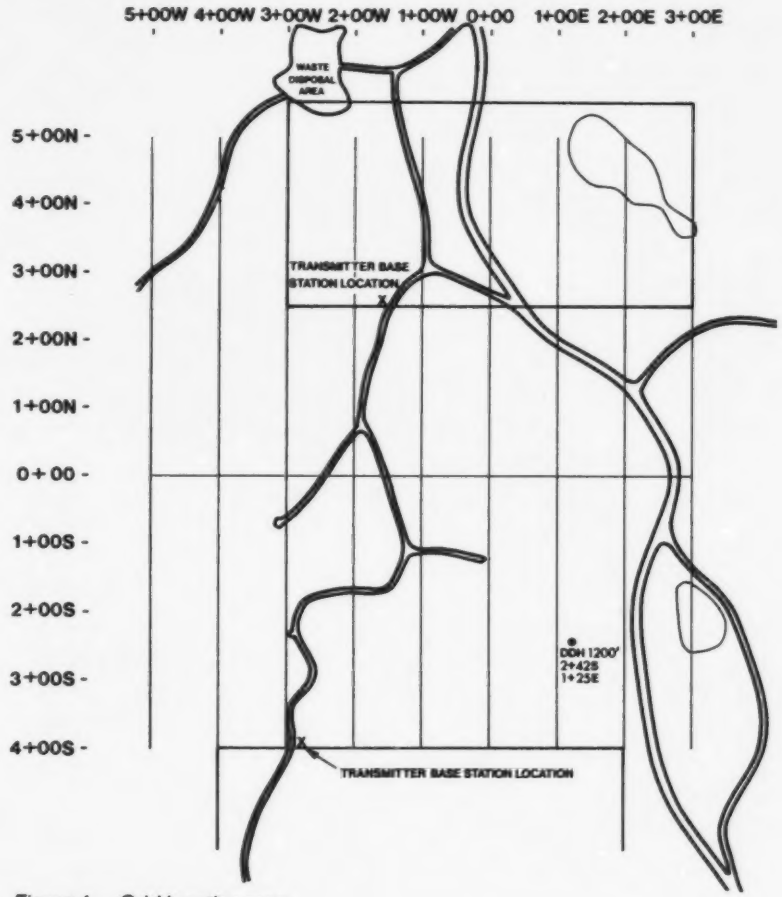

Figure 1— Grid location map

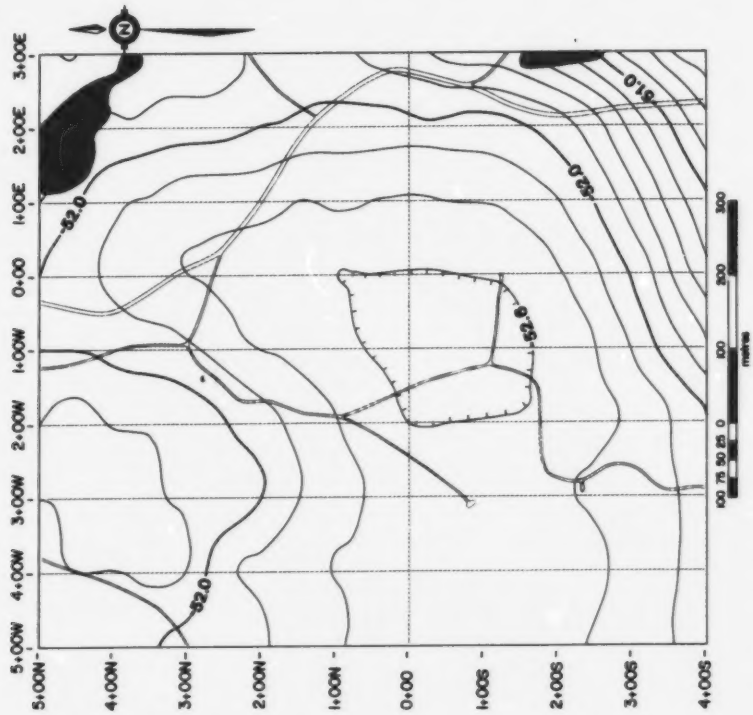

Figure 3—Bouguer gravity contour map. Contour interval is 0.2 milligals.

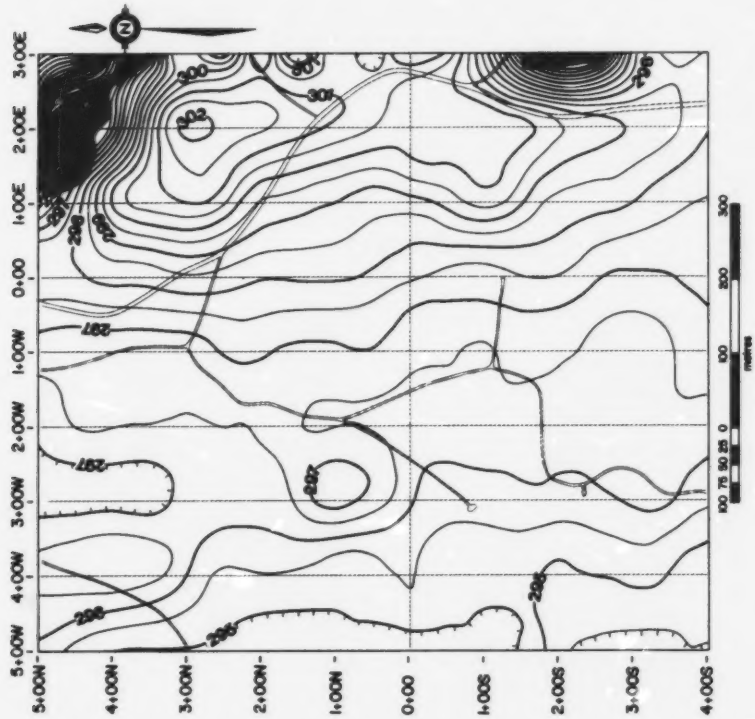

Figure 2—Elevation contour map. Contour interval is 0.5 m.

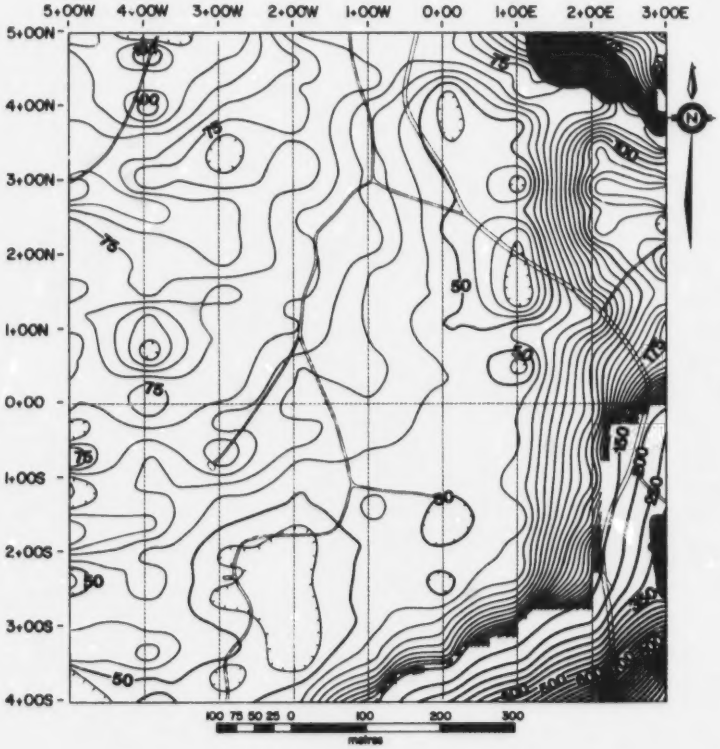

Figure 4—Total magnetic field contour map. Contour interval is 5 gammas. (Base value is approximately 59 000 gammas).

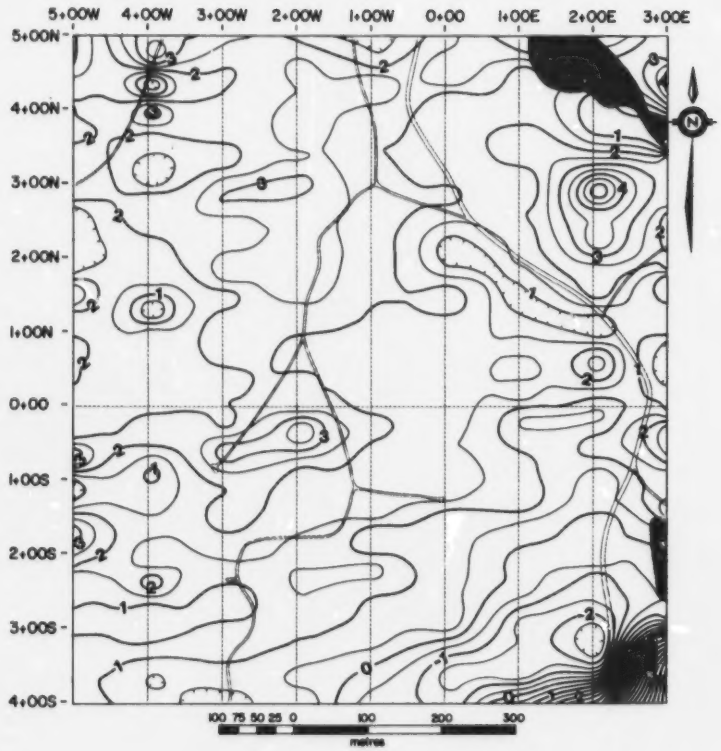

Figure 5—Vertical magnetic gradient contour map. Contour interval is 0.5 gammas/metre.

The vertical magnetic gradient map shown in Figure 5 has been filtered using a low pass filter prior to gridding, however, the presence of high frequency data is evident and is possibly the result of point sources (i.e. magnetic boulders) in the overburden. Further data processing is required in order to utilize the gradient data for interpreting contacts in the bedrock.

Electromagnetic Data

PEM Data

An inline pulse EM survey (PEM), was carried out over 6 lines, 2 West to 3 East, on the grid using a separation of 100 m between the transmitter and receiver. A 7 turn 13.7 m diameter transmitter loop having a dipole moment of 7.223×10^3 A.m^2 (current = 7A) and a turn off time of 1 ms was used throughout the survey. The secondary field in the absense of the primary field was sampled using 8 gates as shown in Table 1. Synchronization between the transmitter and receiver was maintained using a high frequency radio link. The system operates with a fundamental transmitter frequency of 23 Hz or a quarter cycle time base of 10.88 ms.

The data for only 3 lines, 1 West, 0, and 1 East, are shown in Figure 6.

Max Min III Data

In addition to the data obtained last season (Barlow 1981) with a maximum coupled 200 m coil separation, 4 lines, 2 West, 1 West, 0, and 1 East, were surveyed using the maximum and minimum coupled modes and a coil separation of 150 m, and 3 lines, 1 West, 0, and 1 East, were surveyed using the maximum and minimum coupled modes and a coil separation of 250 m. It should be noted that the 3 lines shown in Barlow (1981) are plotted with incorrect vertical scales (±8 percent scales should be substituted for the ±40 percent scales used last year). Data for the maximum coupled mode and 150, 200, and 250 m separations are shown in Figure 7 for line 1 East.

The dipole moments for the the 5 frequencies are shown in Table 2.

TABLE 1 RECEIVER TIME GATES FOR THE PEM SYSTEM HAVING A TIME BASE OF 10.88 ms

CHANNEL	GATE CENTRE μs	GATE WIDTH μs
1	150	100
2	300	200
3	550	300
4	900	400
5	1450	700
6	2400	1200
7	4000	2000
8	6400	2800

TABLE 2 TRANSMITTER OUTPUT FOR MaxMin III

FREQUENCY (f_1)	DIPOLE MOMENT(M)
1777 Hz	75 A.m^2
888 Hz	150 A.m^2
444 Hz	300 A.m^2
222 Hz	550 A.m^2
111 Hz	600 A.m^2

EM-37 Large Loop Survey

In addition to the 5 lines surveyed last season (Barlow 1981) with the large loop centre located at 5+50 South and 1+00 West, 2 lines, 0 and 1 East, were surveyed with a 300 by 600 m rectangular loop centred at 4+00 North and 0+00, and the results are presented in Figures 8 and 9.

These data were obtained using a fundamental frequency of 25 Hz and a transmitter turn off time of approximately 440μs using a current of 15.2 A. The dipole moment of the transmitter in this case was 2.736×10^6 A.m^2. Twenty channels of information were obtained for 3 orthogonal coil configurations using the same gate centres and widths as shown in Table 1 of Barlow (1981).

Preliminary Observation in Electromagnetic Data

Two conductive horizons have been confirmed by the additional electromagnetic data obtained this year. Preliminary EM-37 modelling results indicate the presence of 2 conductive plates dipping toward each other in the vicinity of line 1+00 East and converging toward each other to the west. The tops of the plates are estimated to be approximately 87 m subsurface and located at approximately 0+25 North and 1+50 South on line 1+00 East. The two plates may represent a synclinal fold, or may even represent 2 sheet-like conductors connected at depth (~225 m subsurface). Responses from the PEM survey and the MaxMin III surveys would support this hypothesis in the region of 1+00 East.

Transmitter coupling with the conductive horizons would be affected in an unusual way in that if the transmitter was on the southern side of the conductive bodies, the primary fields generated from the transmitter would couple reasonably well with the southern conductive horizon and poorly with the northern one. Conversely, the opposite case would be observed if the transmitter was north of the 2 conductors. Hence the responses from the 2 plate-like conductive horizons would be cummulative to some extent, between the conductive horizons where shorter coil spacings are utilized.

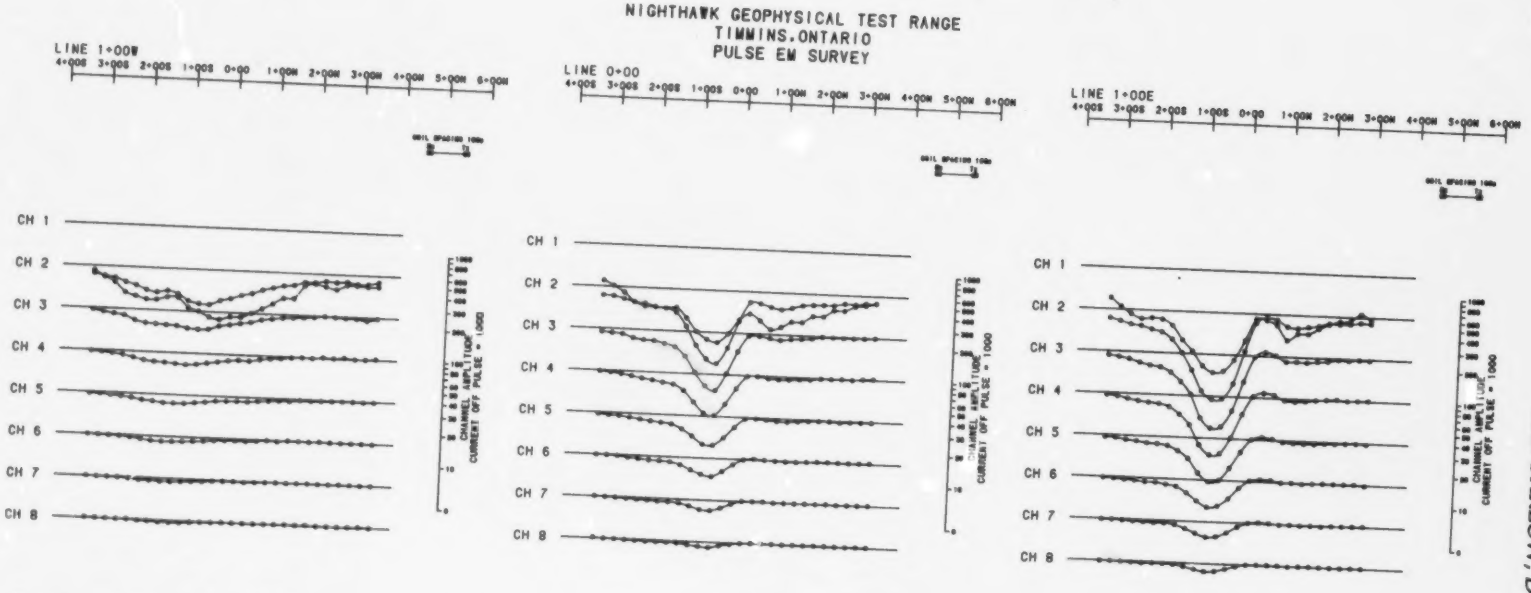

Figure 6—PEM results over 3 lines.

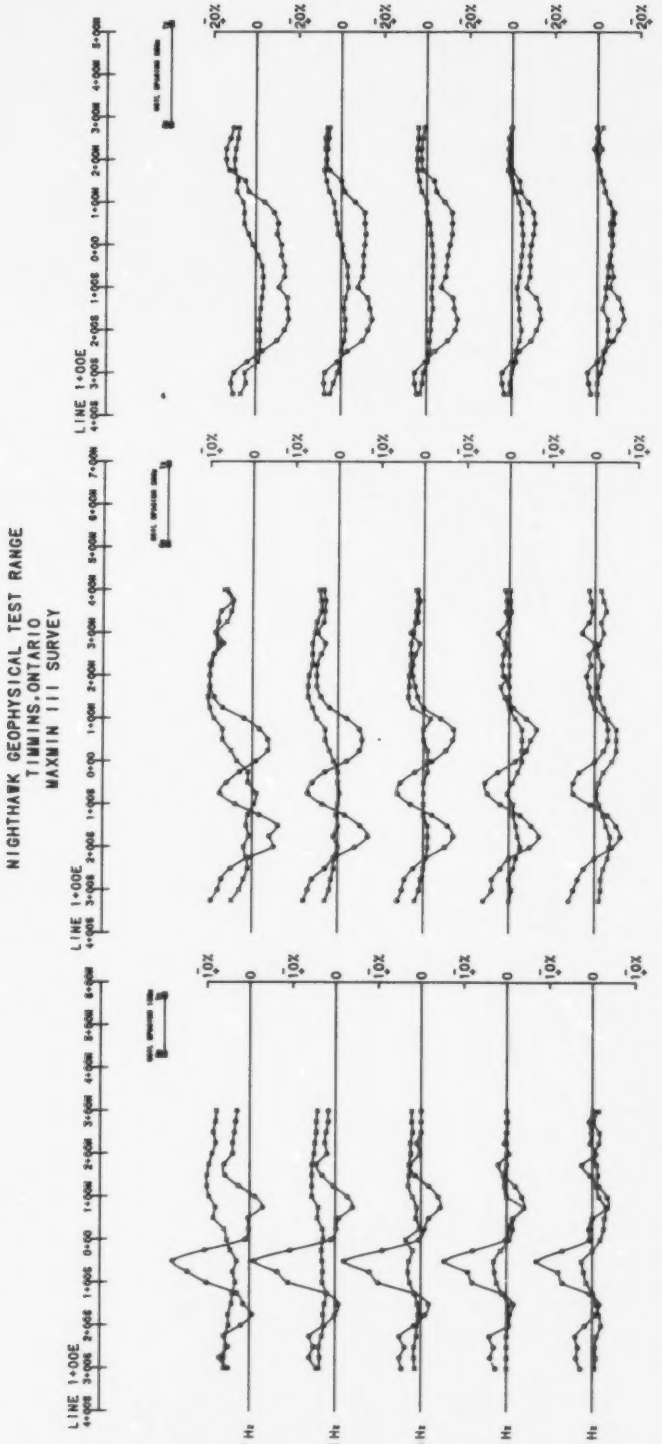

Figure 7—MaxMin III results using 150, 200, and 250 m coil separations over Line 1 East. (In-Phase-Solid lines, Quadrature-Dashes).

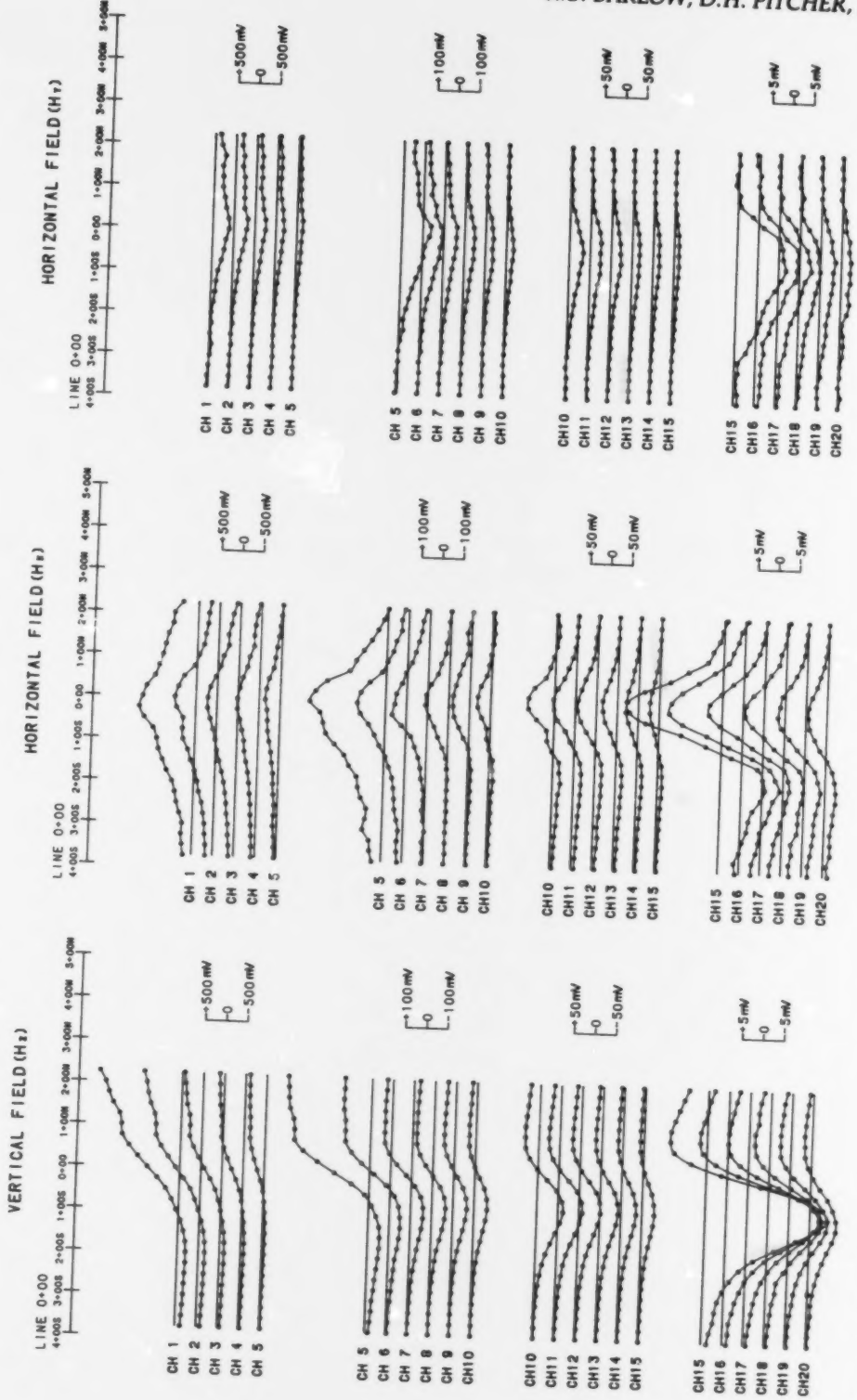

Figure 8—EM37 three-component measurements over Line 0 using north loop.

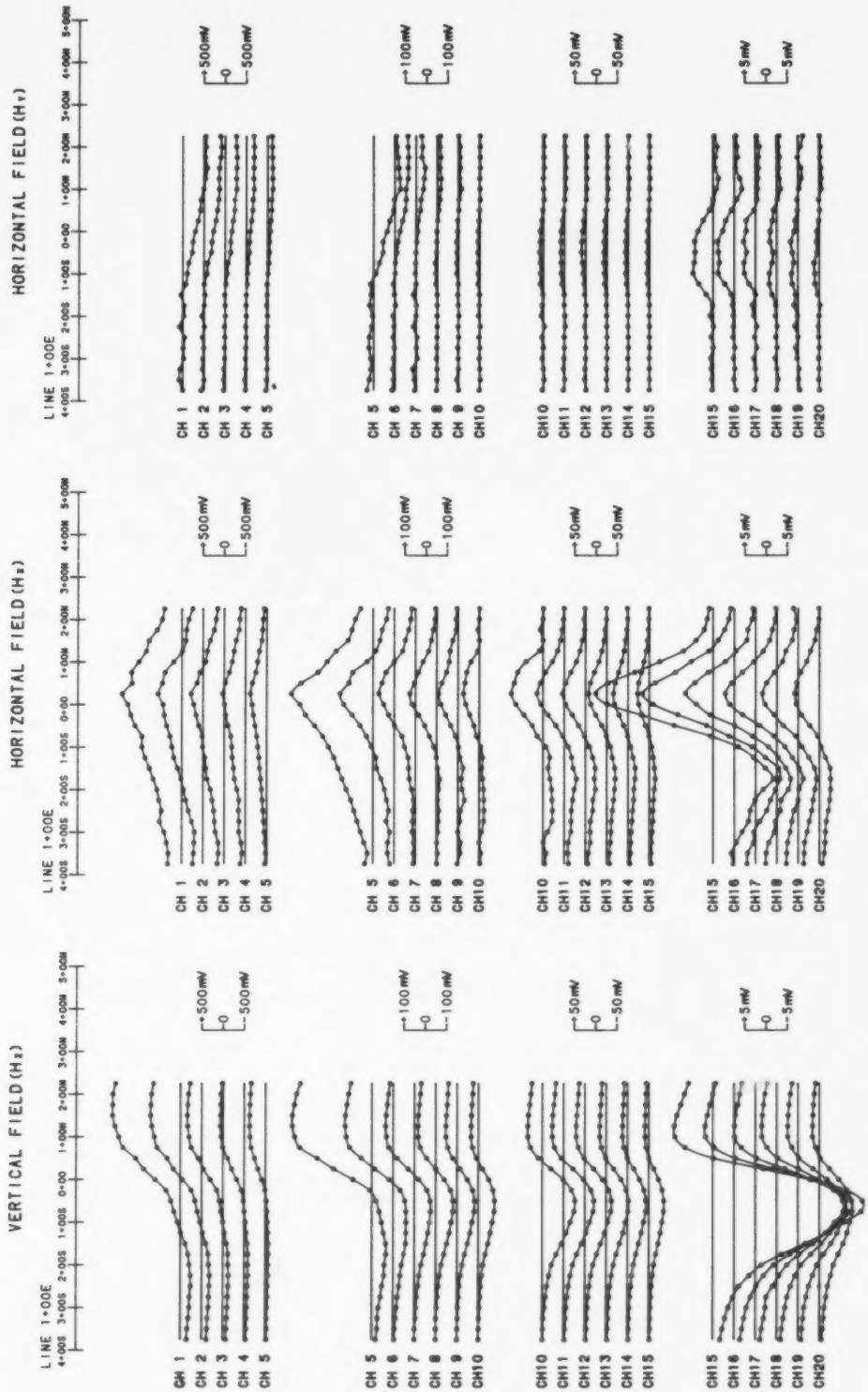

Figure 9—EM37 three-component measurements over Line 1 + 00 East using north loop.

Future Activities

Additional experiments are planned for the next field season as well as continuance of the grid system eastward an additional 200 m. The first of a series of drillholes will be started later in the year in the area of line 1 + 00 East to enable better definition of the conductive horizons, and also to permit electromagnetic borehole logging to be carried out in future years.

An interpretation and synthesis of the data for this test range is scheduled for the following year, and results will be published in mid-1984. The target selected for the test range has proven to be a reasonable challenge for most state-of-the-art electromagnetic inductive systems and associated interpretation techniques.

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1981: Night Hawk Geophysical Test Range Results Using Two Electromagnetic Systems, District of Cochrane; p.152-159 *in* Summary of Field Work, 1981, by the Ontario Geological Survey, edited by John Wood, O.L. White, R.B. Barlow, and A.C. Colvine, Ontario Geological Survey, Miscellaneous Paper 100, 255p.

No. 23 Verification and Standardization of Methods for the Collection of Mineral Exploration/Environmental Information from Lakes in the Vicinity of Wawa, District of Algoma

John A.C. Fortescue[1], R.B. Barlow[2], and D.R. Wadge[3]

Introduction

Detailed investigations by a multidisciplinary team during 1980 (Thomson 1980; Fortescue *et al.* 1981) and 1981 (Thomson 1981) established a firm basis for the inclusion of an environmental component within the traditional techniques of regional geochemical surveying for mineral exploration. The purpose of the 1982 study in this series was to verify and standardize the methodology which had been proven feasible in 1980 and 1981.

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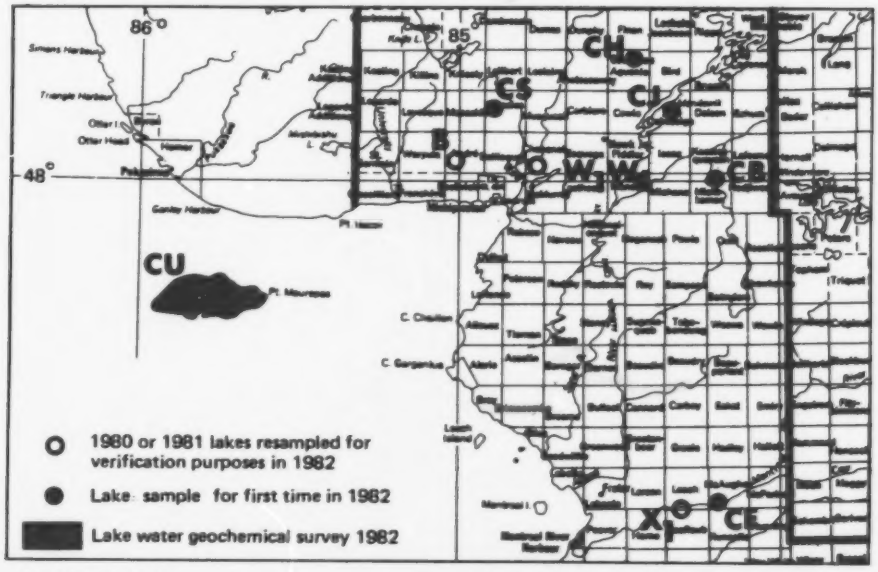
The environmental problem of greatest concern in the 1980 and 1981 studies was that of acid precipitation. In 1980 the team, consisting of a geochemist, a limnologist, and a palynologist, showed that lakes in the Wawa area most likely to be susceptable to the effects of acid precipitation have waters with low pH, low alkalinity, and low calcium content. Additional research, completed in 1981, indicated that the pH of lake waters is directly related to the diatom flora on the lake bottom, and that if the lake sediment material within a core is examined, the pH history of the lake can be established. Other observations suggested, but did not prove, that the descriptive geochemistry of lake sediment cores might also be used as an indicator of paleo pH. The fieldwork during 1982 was designed to examine these relationships further and to establish a routine for regional geochemical surveying, which included an environmental component for the study of acid precipitation and related problems.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

TABLE 1 VERIFICATION TEST OF LAKEWATER CHEMICAL DATA

LAKE	pH		ALKALINITY		Ca	
	1981	1982	1981	1982	1981	1982
			Meq/L		ppm	
B*	5.0	5.19	0.33	0.50	1.5	1.8
W_1	6.7	6.88	.265	.332	57.0	21.6
W_4	7.34	7.69	.365	.469	21.4	24.2
X_1	5.02	5.57	.024	.043	1.4	2.2

*First sampled in 1980, not 1981

The 1982 study involved the collection of lakewaters and lake sediment cores in the vicinity of Wawa, and at Michipicoten Island. As in previous years, the limnological activity was under the direction of M.J. Dickman, and the palynological studies were directed by J. Terasmae, both of Brock University.

Objectives

The objectives of this study were:

1. to standardize and verify methods for regional geochemical surveying involving an environmental component designed to study acid precipitation and related problems
2. to complete diatom paleo pH/descriptive geochemical research in order to establish the feasibility of using geochemical data for the estimation of the pH history of lakes

Methodology

The 1980/1981 team was reformed under the direction of the senior author. The field party included R.B. Barlow and D.R. Wadge of the Ontario Geological Survey (who were involved in the Michipicoten lakewater survey), and M.J. Dickman, J.Ciolfi, and M.A. Leyland from Brock University, who were largely concerned with the study of lakes around Wawa. It was unfortunate that Professor Terasmae was unable to join the field party this year. In Wawa, active support was provided by S. Kerr, Fisheries Biologist at the Wawa District Office of the Ontario Ministry of Natural Resources.

Resulting from the 1980/1981 experience, a new method of sampling lake sediment cores was used in 1982. This involved subsampling cores in the field laboratory to obtain material for geochemical, limnological, and palynological study. One advantage of this procedure was that it obviated the need for freezing the cores prior to subsampling. Otherwise the methods for the collection and processing of lake waters and sediment cores was the same as in previous years.

In addition, the 1982 study had 2 experimental components. One was to attempt surficial mapping of selected lake catchment areas based on prior air photograph interpretation followed by helicopter fly-bys of the lake shorelines. The other was an experimental lakewater survey of Michipicoten Island, designed to obtain information on the pH and alkalinity of lake waters in the field laboratory on a day-to-day basis.

Acknowledgments

The Algoma Ore Division of Algoma Steel Corporation Limited are thanked for their permission to carry out sampling of lakes on private lands northeast of Wawa. Steve Kerr provided helpful advice regarding the selection of lakes for study and also loaned us reports, data files, and bathymetric maps. He also loaned some laboratory equipment to M. Dickman.

Preliminary Results

Verification of lakewater chemical data from year to year is seldom exact due to within season, and season to season effects. Verification is further complicated within the context of regional geochemical surveying because traditionally only 1 sample is collected per lake per year. Data in Table 1 indicates the magnitude of this problem in 4 lakes selected for tests.

Our belief that the pH of lakes does not vary more than half a unit from year to year is confirmed over the range pH 5.0 to 7.3. This is the critical range in acid precipitation studies because sensitive lakes have a pH of 5.6 or lower. As expected, the alkalinity is more variable, although it is reproducible within a given order of magnitude which is suitable for a first approximation in acid precipitation studies. The reproducibility of the calcium levels is similar to that for alkalinity except in the case of lake W_1, which lies in the Wawa smelter plume fume kill area. The good data for lake W_4, which is situated downstream from lake W_1, suggests that the high calcium in lake W_1 in 1981 may be a local effect.

Table 2 lists data for pH, alkalinity, calcium, and sulphate for other lakes included in the 1982 study.

TABLE 2 LAKEWATER CHEMICAL DATA FOR SEVEN LAKES INCLUDED IN THE STUDY

LAKE	pH	ALKALINITY Meq/L	CALCIUM ppm	SULPHATE ppm
CB_1 (1)	4.92	0.050	0.4	6
CB_2 (2)	5.05	0.026	0.6	–
CE (3)	5.45	0.041	1.6	8
CH (4)	3.25	–	23.0	207
CJ (5)	6.44	0.122	3.6	11
CJ (6)	6.63	0.115	4.4	11
CU (7)	6.08	0.043	2.0	–

These lakes were selected on the basis of the data from the traditional regional geochemical survey or on the advice of S. Kerr. Briefly, lakes CB_1, CB_2, and CE were chosen on the basis of data from the previous survey. As expected, low pH was accompanied by low alkalinity, calcium, and sulphate. Lakes CJ and CS were of intermediate pH with alkalinities and calcium levels an order of magnitude higher than those of the previous group. Lake CU, situated on Michipicoten Island, was of interest because although the pH was relatively high, alkalinity, calcium, and sulphate were all low. Lake CH was included as an extremely acid lake due to its use as a tailings dump for a mine.

Work on the lake sediment cores will be completed during the winter, and described in an Open File Report being prepared for early 1983.

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No. 24 Gravity and Aeromagnetic Studies in North-Central Ontario: A Progress Report

V.K. Gupta[1]

Introduction

This progress report summarizes the status of data synthesis and interpretative studies being carried out on gravity and aeromagnetic data in north-central Ontario. It describes various computer-processed maps that have been prepared for this study utilizing signal enhancement techniques. The gravity data were collected during the summers of 1973, 1977, 1979, and 1980 (Gupta and Wadge 1980a, 1980b; Gupta 1981a, 1981b) covering an area of approximately 33 000 km². The gravity coverage is relatively dense; over 7200 gravity stations were surveyed at an average station distribution of one station per 1.5 km² in areas of high mineral potential. Over 3400 rock

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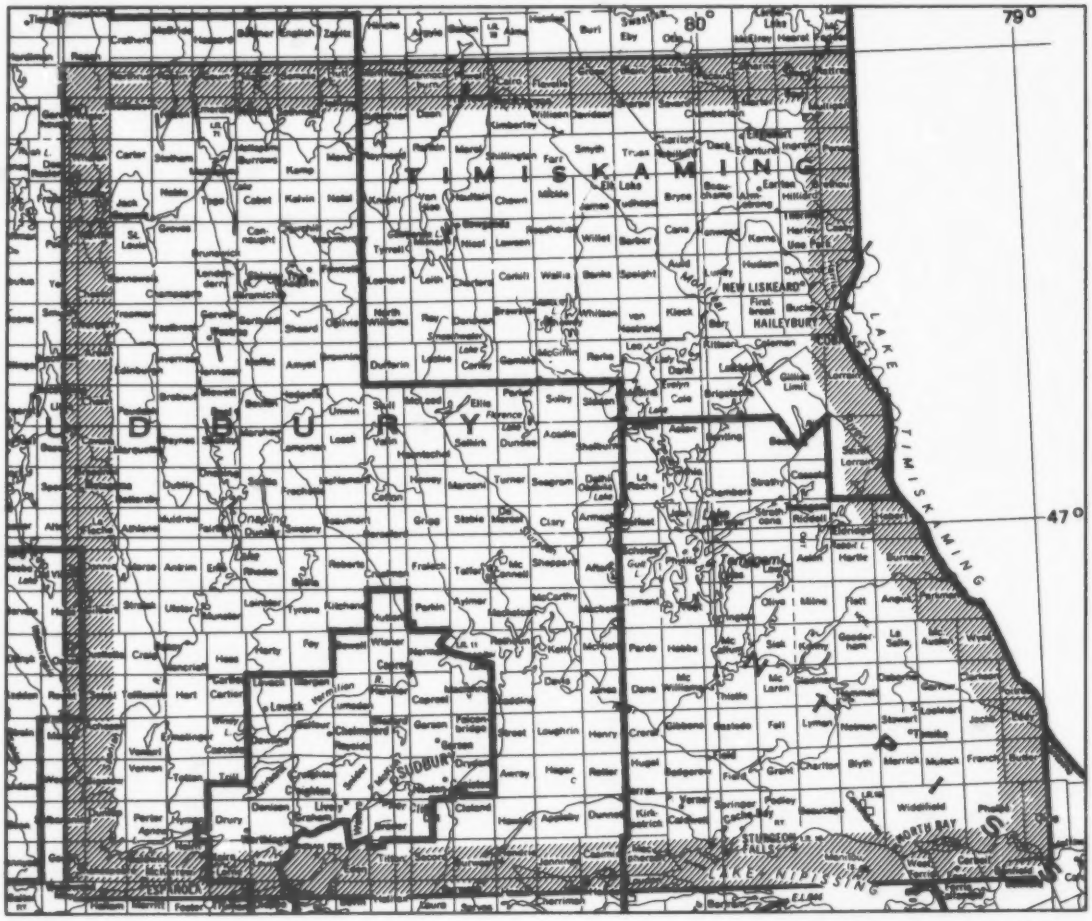

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

density measurements were made on fresh rock samples simultaneous to the undertaking of the gravity field work. In addition, this study also includes data from over 3625 gravity stations established primarily in the Sudbury area by the Department of Energy, Mines, and Resources of Canada, in the late 1960s (Popelar 1971, 1972).

In order to reduce certain interpretation ambiguities from the gravity data, and to obtain reliable estimates on the thickness of the Huronian metasediments, eighteen ODM-GSC aeromagnetic maps were digitized along 0.5 mile spaced flight lines. This survey was flown during 1959 and 1960 at a mean terrain clearance of 1000 feet. Theoretically, the magnetic anomaly detail is quite sufficient to obtain good estimates of the depths of magnetic bodies that are more than a few hundreds of metres below the ground surface. Since there is very little factual information concerning the extent and depth of burial of the Nipissing Diabase, the decision was taken to analyze as many anomalies as possible within the Cobalt Embayment, and to separate the suprabasement bodies (diabase) from intrabasement units (e.g. Early Precambrian iron formations) according to the calculated depths, dips, and magnetic characteristics.

The study area includes parts of the Superior, Southern, and Grenville Provinces. It is a region of considerable geological complexity, which includes both volcanic and intrusive rocks of widely different compositions and ages, as well as large areas of metasediments and numerous sills and dikes of diabase. Structurally, it is dominated in the southern part by the contact zone between the Superior and the Grenville Provinces. The Grenville rocks on the southern side of the contact consist largely of paragneisses which are intensely deformed, with significant intrusions of anorthositic gabbro close to the contact zone. The Superior rocks to the north contain a few small "greenstone belts", a number of medium- to large-sized granitoid intrusions, and very widespread occurrences of Nipissing Diabase. A large part of the Superior region is covered with a blanket of Proterozoic Huronian metasediments, of unknown thickness, known as the Cobalt Embayment, which conceals the underlying Early Precambrian basement lithology.

The study area includes the Sudbury Basin and the Cobalt-Temagami mining camps, and is considered to have a high economic potential. Much of the interest is centred on searching for potential Witwatersrand-type gold deposits in the sedimentary covered regions of the Cobalt Embayment.

Bouguer Gravity Map

The Bouguer gravity contour map reflects the geological complexity of the area, and reveals some very broad anomalies due to large, deep-seated masses in addition to the effects of density changes which occur in the rocks near the surface. Some of the major geological units such as the Sudbury Irruptive, the Shining Tree, Benny, and Temagami "greenstone belts", the Round Lake Batholith, the Lorrain granite, and other felsic intrusions show up remarkably well in the Bouguer gravity contours. However, the gravity fields of these units overlap one another to a considerable extent, and therefore a regional-residual analysis of the Bouguer gravity field was necessary.

Regional Gravity Map

The regional-residual analysis was carried out graphically on the Bouguer map by estimating local gravity base levels along north-south and east-west profiles which form an orthogonal 9 by 9 km grid covering the study area. In the regional gravity contours there is no trace of the boundaries between the Grenville, Superior, and Southern Provinces. It would appear, therefore, that no important compositional differences between Superior and Grenville rocks persist through large volumes of the crust.

Residual Gravity Map

The map of residual gravity is obtained by subtracting the regional gravity anomalies from the Bouguer gravity values. The residual gravity contours clearly outline many important features that are already known, such as the Shining Tree, Temagami, and Benny metavolcanic-metasedimentary belts, including their felsic and mafic subdivisions, the Round Lake Batholith, the Sudbury Irruptive, and the anorthosite-gabbro intrusions to the east of Sudbury. It also indicates a number of features which have not been mapped, such as a negative mass comparable in size to that of the Round Lake Batholith lying immediately to the south of it, and a possible extension of the Temagami volcanic rocks beneath Huronian metasediments. The residual gravity contours fail to provide any information on the thickness of the Huronian metasediments because there is insufficient density contrast between the Huronian metasediments and the underlying basement (Early Precambrian) rocks to produce an observable gravity effect. In fact, no variations in residual anomaly amplitudes occur which can be correlated with the areas of sedimentation. Regrettably, therefore, the gravity data cannot be used in any direct manner to map the thickness of the Huronian metasediments.

Vertical Gravity Gradient Map

This map was done by computer from gridded Bouguer gravity values using the Fourier transform method. Large-scale structures such as the Timiskaming and Cross Lake faults, as well as other major lineaments, show up as vertical gradient "lows", indicating that the fracture zones tend to be filled with low density rocks rather than with diabase or other heavy mineral-rich rocks. The vertical gradient contour map enhances the near-surface geology into sharper relief and has been used primarily to locate the boundaries between the different rock density units, which should correspond with significant changes in rock mineralogy. This information has been used as an aid in developing a map of the Early Precambrian basement lithology.

Second Vertical Derivative Gravity Map

A map of the second vertical derivative of the Bouguer gravity field was calculated by operating upon the gridded Bouguer gravity data in the frequency domain. The contours of the second vertical derivative map will be used as an aid to mapping lithologies, as well as an aid in resolving weak overlapping anomalies.

Apparent Density Map

An analytical tool called "apparent density mapping" has been employed to resolve the different lithologies from the residual gravity contour map. The algorithm is similar in concept to that of "apparent susceptibility mapping". Apparent density values are calculated directly from the residual gravity grid by performing a deconvolution, assuming that the bedrock density varies horizontally but not vertically within a prescribed distance below the ground surface. A contour map of the apparent density of the bedrock to a depth of 6 km has been computed. The density contours give clear outlines of the ultramafic, mafic, and felsic units. In the areas where the Early Precambrian rocks are exposed, the correspondence with geological mapping is excellent; accordingly, this has enabled mapping of the distribution of major lithologies of the basement complex beneath the Huronian metasediments with considerable confidence.

Vertical Gradient Magnetic Map

To make small anomalies more visible and sharper, a vertical gradient map of the geomagnetic field over the Cobalt Embayment was calculated from the total field data. The magnetic diabase intrusions have been outlined from this map. This map does not show all of the diabases within the Cobalt Embayment, since there are probably some that are non-magnetic, but the vertical gradient magnetic map does give a general picture of the horizontal distribution of diabase intrusions.

Cobalt Embayment

The Cobalt Embayment, being a shallow, intracratonic basin of Middle Precambrain age, is thought to have some potential for Witwatersrand-type reef gold deposits which, in Witwatersrand itself, are known to be controlled by paleogeomorphology. Due to a lack of density contrast between the metasediments and the underlying basement rocks, the gravity survey has been unable to provide any useful depth estimates on the thickness of the Huronian metasediments. It has also been observed that many of the aeromagnetic anomalies in the Cobalt Embayment originate from intrusions of diabase-gabbro into the metasediments as well as from bodies of diabase-gabbro within the basement rock. It is, therefore, difficult to perceive any characteristics of these anomalies that would distinguish them from magnetic anomalies which have their origin in the basement rocks or metasediments. Fortunately, Early Precambrian iron formations, although few in number, definitely belong to the basement complex and are an easy target to recognize on the aeromagnetic maps. From an analysis of aeromagnetic anomalies due to buried Early Precambrian iron formations, the thickness of the Huronian metasediments has been calculated to range from 900 to 1800 m. A conjectural picture that emerges from the combined study of gravity and aeromagnetic data over the Cobalt Embayment is an Early Precambrian basement which is divided into two probable regions. The western half of the embayment appears to be granitic with gentle relief. The eastern half of the embayment appears to be "greenstone" type, with comparatively rugged relief characterized by paleovalleys and paleohighlands having a topographic relief that is probably several hundreds of metres. Since the geophysical evidence upon which this interpretation is based is indirect, the conclusions just stated must be accepted with proper reservation.

The interpretation of the gravity data is now in its final stages. In the near future, two- and three-dimensional gravity models of the "greenstone belts", major batholiths and plutons, as well as the thickness of the Nipissing Diabase sheets will be computed using, as controls, the mapped or interpreted geological boundaries and the bulk density values indicated by the apparent density contours and supported by the surface density measurements.

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No. S19 Descriptive Geochemistry and Descriptive Mineralogy of Basal Till in the Kirkland Lake Area, Districts of Timiskaming and Cochrane

John A.C. Fortescue[1] and Jeanette Lourim[2]

THIS PROJECT WAS PART OF THE KIRKLAND LAKE INITIATIVES PROGRAM (KLIP) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NORTHERN AFFAIRS UNDER THE COMMUNITY AND RURAL RESOURCE DEVELOPMENT SUBSIDIARY AGREEMENT.

Introduction

Applied geochemical studies continued in the Kirkland Lake area during 1982. This work forms part of the Kirkland Lake Initiatives Program (KLIP), a joint Federal-Provincial project, designed and managed by the Ontario Geological Survey, that will provide a comprehensive geoscientific database for the area.

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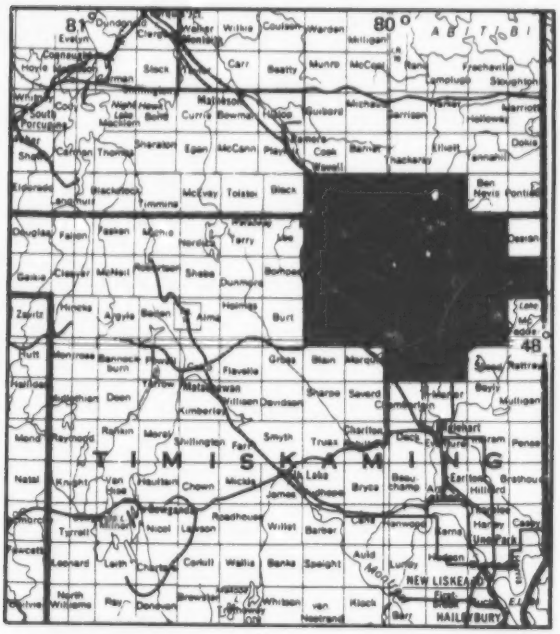

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

This year continued the systematic surveying activities commenced in 1979. The area studied lies between the Little Clay Belt, and the Greater Abitibi Clay Belt, and was the site of a major lake basin during the retreat of the Wisconsinan glaciation. An extensive cover of glaciolacustrine clay and glaciofluvial sand precludes the use of conventional geochemical prospecting techniques in large parts of the area. Consequently, special methods of descriptive geochemistry and descriptive mineralogy are required to locate mineralization in the area.

Reverse Circulation Rotary Drilling

The 1982 drilling program was a continuation of that commenced in 1979, and employed the same techniques as those described by Thomson and Guindon (1979), Averill and Thomson (1981), and Routledge *et al.* (1981).

The 1982 program involved 50 holes with a total length of 1270 m of drilling. Drilling was completed in Hearst, Catherine, McElroy, Gautier, Arnold, Clifford, and Bisley Townships. The 1982 drilling was carried out well to the north, or south, of the principal structural and stratigraphic features which control the major known gold deposits of the Kirkland Lake area. At present it is assumed that all of the glacial material in the 1982 drill areas was deposited in one ice advance and retreat during the Wisconsinan.

Chemical and mineralogical studies of the samples collected during the 1982 drilling program are presently being undertaken, and the results will be published before the end of 1982.

Compilation and Interpretation of the KLIP Data

The KLIP descriptive mineralogical and descriptive geochemical data has been published in a series of Open File Reports: Averill and Thomson (1981); Routledge *et al.* (1981); and Thomson and Lourim (1981). Three further publications in this series are currently underway (two by

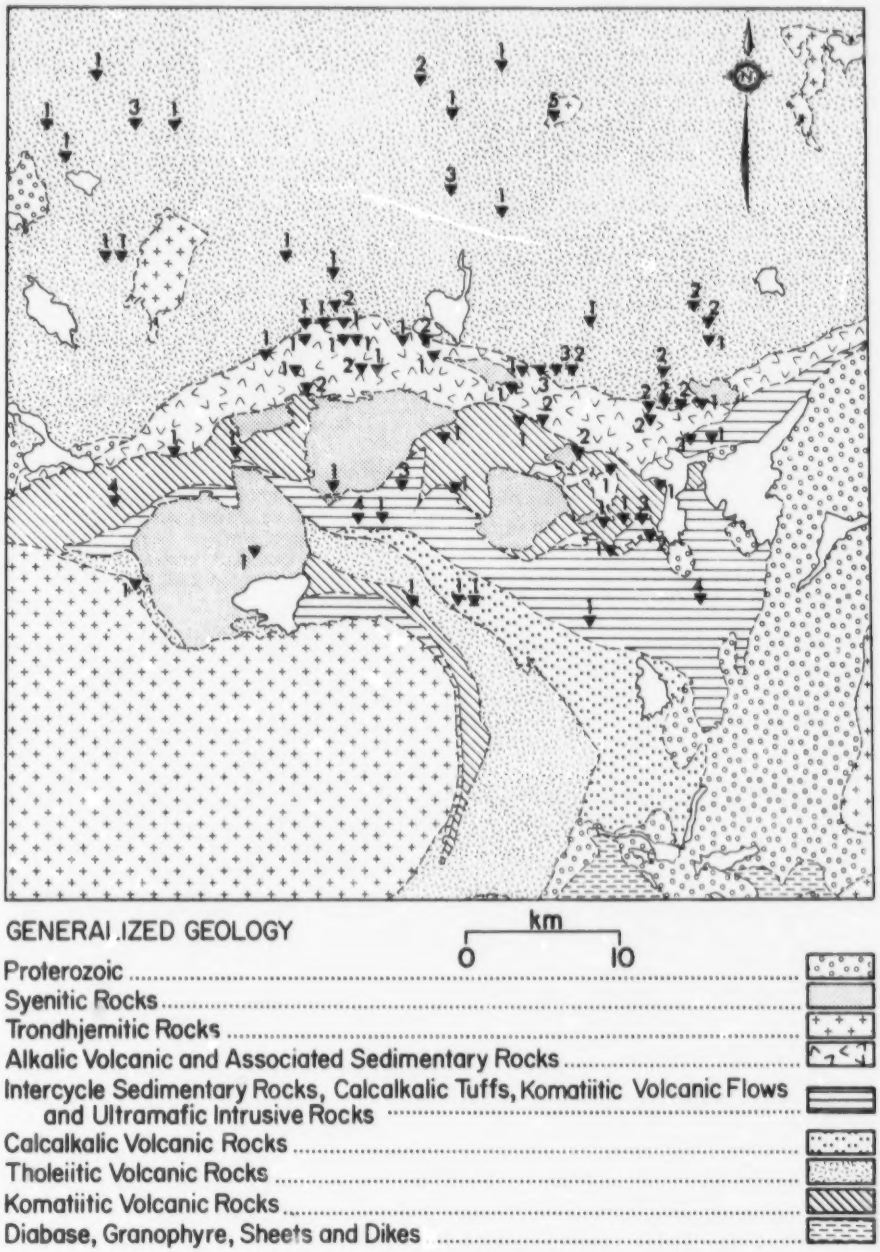

Figure 1—An example of an interpretative pattern map of the Kirkland Lake Initiatives Program (KLIP) area. Inverted triangles indicate number of gold particles seen on the shaking table during sample preparation. Location of sample points is approximate.

Lourim, and one by Averill and Fortescue). Other articles and short reports on the KLIP database have also appeared: Thomson and Guindon (1979); Thomson and Wadge (1980); Lourim and Thomson (1981); and Thomson and Wadge (1981). Because the project is now in an advanced stage, the time has come for synthesis, analysis, and interpretation of the geochemical and mineralogical data and information in relation to geological, geophysical, and other information obtained from the same general area.

Since May 1982, an effective, simple, and innovative method for the examination of multidisciplinary earth science data from the KLIP area has been designed by the senior author, and implemented by the Ontario Geological Survey staff. It involves a series of 1:250 000 scale maps and overlays, which can be combined in order to focus attention of relationships between the more than 200 data subsets which have accumulated during the course of the project. Because the basal till information is considered to be of greatest interest to the exploration community, the compilation procedure has focused attention on the 327 samples of this material which were collected from the area during the period 1979 to 1982.

Figure 1 illustrates the format of an interpretative pattern map. It includes data for the number of gold particles observed on the shaking table (used for sample preparation of basal till) combined with a map showing the major lithological units of the area. A map of this type is used as a guide to the location of sample points and areas of interest which are then examined in detail with reference to the Open File Reports. An Open File Report including over 100 interpretative pattern maps and related information is currently being prepared.

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Mineral Deposits Programs

Summary of Activities, Mineral Deposits Section, 1982

A.C. Colvine[1]

During 1982, the Mineral Deposits Section attained its full staffing level of 7, including 5 staff geologists. The activity level of the Section was supplemented through employment of contract project geologists, joint projects with regional geological staff, and cooperative projects with university staff geologists. Several community-based and commodity-oriented projects, supplementary to the base program, were carried out through funding provided by the Ontario Ministry of Northern Affairs, the Federal Department of Regional Economic Expansion, and the Ontario Ministry of Natural Resources. Acknowledgment of the funding source is included in individual reports.

The program of the Section is designed to develop expertise in and provide information on all aspects of the geology of mineral deposits in Ontario. This program is carried out through a combination of improvement of the mineral deposits geological data base and applied research into their geology and genesis; as such the Section is attempting to bridge a gap between universities and the exploration industry by investigating the direct application of recent advances in mineral deposits research into exploration. Development of metallogenetic concepts and models is a general goal but cannot have strict production targets.

The large number and diverse range of mineral deposits in Ontario, and the limited resources of the Section preclude simultaneous comprehensive projects in all geological areas. While staff geologists can maintain general expertise over the broad range of mineral deposit types, it is necessary to focus the new geological work of the Section through working groups on more specific topics, which have the potential to produce significant results within a reasonable time period. The main thrust at present is an investigation of Early Precambrian (Archean) lode gold deposits, involving the cooperative project work of 7 geologists. As this topic develops, it is hoped that emphasis can be shifted from studies of the known deposit types to investigations of gold in previously unrecognized associations. A second program area is the geology of metallic and industrial minerals in the Grenville Province, involving 6 geologists. Four more limited projects are underway to investigate sedimentary and vein mineralization in the eastern Southern Province. In addition, there are several projects underway to investigate more general aspects of metallic and industrial minerals in the province.

The Early Precambrian gold program has been developed to simultaneously examine several of the characteristic geological associations of gold mineralization, and thereby construct a comprehensive picture of the factors which result in gold concentration. The program to date has included a preliminary field and comprehensive literature study (Cherry *et al.* 1982), and the development of field-based projects during the 1982 field season is to be followed by laboratory studies during the winter. All of the projects outlined below are being carried out in the context of their complete geological setting and are closely coordinated with each other.

M.E. Cherry (this volume) is undertaking a study of the association of gold with felsic intrusions; initially the work has been focused on deposits of the Abitibi Belt. A.James Macdonald (this volume) is investigating the association of gold with iron formation with initial work being carried out in the Geraldton area; inevitably, this project has also involved a structural study of the area. A.J. Andrews (this volume) is studying alteration associated with gold, initially in the Red Lake camp; this project is attempting to unravel the complex alteration history of the rocks adjacent to gold concentration. It is closely coordinated with

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the work of M.E. Durocher and S. van Haalten (this volume) who are investigating the geological association of gold deposits in the Red Lake camp; this year's component has involved detailed mapping of the stratigraphy and alteration of the Madsen gold area. The work of K.H. Poulsen is a comprehensive metallogenetic study of the Fort Frances-Mine Centre area (Poulsen 1981), but specific work on the structural controls on gold is an integral part of this program. C.J. Hodgson (this volume) has constructed a comprehensive computer file of the geological characteristics of all gold deposits of the Abitibi Belt of Ontario; this work has involved some field work to assist in stratigraphic re-evaluation. The study of F.R. Ploeger on the Kirkland Lake Main Break (Ploeger 1981) is continuing at McMaster University.

Several other projects in the Superior Province are nearing completion. Soussan Marmont is completing the study of mineralization associated with Early Precambrian (Archean) granitoid intrusions, or "porphyries" (Colvine and Marmont 1981); this work is also contributing to the knowledge of gold associated with these bodies. The work related to this project by P. Studemeister on the Gutcher Lake Stock (Studemeister 1978) was completed this year (Studemeister 1982). F.M. van Soeren is undertaking a study of uranium and associated mineralization in the Kirkland Lake area as part of the Kirkland Lake Initiatives Program (KLIP). S.J. Wilkinson is completing his study of the copper-platinoid mineralization in the marginal phase of the Coldwell Alkalic Complex (Wilkinson 1978) at Carleton University. A Mineral Deposits Circular documenting the gold deposits of the Atikokan area has been published (Wilkinson 1982).

There is a substantial amount of work being carried out in the Grenville Province of Southern Ontario as part of both the Section base program and the Southern Ontario Geological Survey (SOGS) Program. Janet S. Springer is coordinating this work and has been investigating the structural associations of gold mineralization (Springer, this volume) and the sedimentary conditions of graphite formation (Springer, this volume). T.R. Carter is completing a multi-year study of the metallic mineral deposits of the Grenville Province (Carter 1981) and is presently preparing a comprehensive report on the mineralization in the area and, with J. Malczak, a Mineral Deposits Circular. E.P. Dillon and P.S. Barron (this volume) are conducting a 1-year study of selected talc and graphite deposits. The study of the Cordova Gold Mine is continuing at Ottawa University (Thomas 1981). A detailed map of the geology and mineral deposits of the Bancroft area has been published (Masson 1982).

The Section's resources have been inadequate to allow a full program to investigate sedimentary gold and vein silver in the Cobalt Embayment. A.C. Colvine continued his study of gold in the Lorrain Formation at a limited level (Colvine 1981). Analytical results show areas of anomalous gold, the most consistent being the hematite orthoquartzite member of the formation on the western margin of the embayment in Leonard and North Williams Townships; values of up to 1.4 parts per million (0.04 ounce per ton) have been obtained from this unit, representing a greater than 700 times enrichment above the background in the Lorrain. D.F.G. Long and C.A. Leslie (this volume) carried out a sedimentological study of Gowganda Formation paleo-valleys extending northward from the north margin of the embayment; the study of the Mississagi Formation at the southern margin of the embayment (Long 1981) is nearing completion. Leo Owsiacki (this volume) completed mapping of the Gowganda and Lorrain Formations and associated diabase intrusions in the Lundy Township area, highlighting all occurrences of mineralization. In a cooperative project with the Resident Geologist in Cobalt and with the University of Western Ontario and Memorial University, A.J. Andrews, Leo Owsiacki, R.W. Kerrich, and D.F. Strong, (this volume) initiated a study of the silver vein system and associated alteration in the Cobalt-Gowganda area; this work will involve stable isotope and fluid inclusion investigation.

There has been a substantial amount of work carried out in industrial minerals geology, province wide, as part of the base program of the Section and also the Northern Industrial Minerals Program (NIMS). New initiatives in this area, and information concerning active properties are summarized by M.A. Vos (this volume).

During 1982, the Ministry of Natural Resources Land Use Planning process was reaching its final stages. This necessitates considerable input by Section members, particularly Janet S. Springer, A.C. Colvine, and M.A. Vos. A 1 inch to 16 mile series of mineral

potential maps was prepared for Ontario (Springer *et al.* 1982) and many of the District open houses were attended by Section staff.

A revised series of Uranium and Thorium Deposit maps and a Mineral Deposits Circular Open File were released for Northern Ontario (Robertson 1982).

In addition to preparing publications, members of the section made presentations at numerous meetings throughout the year on topics related to their project work.

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No. 25 Felsic Intrusion Associated Lode Gold Deposits in the Matheson Area, Cochrane District

M.E. Cherry[1]

Introduction

Although a close spatial relationship between Early Precambrian (Archean) lode gold deposits in Ontario and felsic intrusions has long been recognized, the role of the intrusions in the formation of these deposits remains enigmatic. This summary presents preliminary data from two such gold deposits, the Canadian Arrow and the Murphy-Garrison, near Matheson in the Abitibi "greenstone belt" that were selected because of their apparent geological simplicity for this study, which is part of a more comprehensive study of gold metallogeny by the Mineral Deposits Section.

Geology of the Deposits

The Canadian Arrow Deposit is located approximately 1.5 km west of Highway 11 in the southwestern corner of Hislop Township and is accessible by a gravel road that leaves the highway about 11 km south of Matheson. The deposit has a lengthy history of exploration and development which, except for work since 1974, is summarized by Prest (1957, p.35) in his report on the geology of Hislop Township. Pamour Porcupine Mines Limited removed some 300 000 tons of ore with an expected average grade of 0.066 ounce gold per ton from the deposit by open pit methods from 1974 to 1982. Mining ceased in May 1982 and the pit is now flooding.

The Murphy-Garrison Deposit is in south-central Garrison Township and can be reached by a gravel road that runs south for approximately 6.5 km from Highway 101 at Twin Lakes, 38 km east of Matheson. Exploration and development of this deposit from 1919 to 1947 are summarized in Satterly's report (1949, p.20) on the geology of Garrison Township. The deposit was mined in 1981 by Kerr Addison Mines Limited, which removed 63 500 tons of ore with an expected average grade of 0.14 ounce gold per ton from an open pit. As at the Canadian Arrow Deposit, mining has stopped and the pit is flooding.

Locations, simplified geological maps, and structural data for the deposits are given on Figures 1 and 2 and field observations are summarized in Table 1. No visible gold has been reported from either deposit; rather, the gold in both is intimately associated with pyrite that apparently formed during alteration that accompanied the emplacement of quartz-carbonate veins into fractures.

At the Canadian Arrow Deposit, the ore-associated veins occur in the intrusion, which is a quartz-poor monzonite; there are 3 well defined directions of veins and each of these directions corresponds to a strongly developed fracture set (Figure 1). The veins are 0.5 to 10 cm wide and can be distinguished by their mineralogy and alteration; the earliest vein set dips to the northeast, has not visibly altered the monzonite, is often vuggy, and carries galena, pyrite, and rare chalcopyrite. The youngest set strikes northeast and has steep dips, contains pyrite and rare chalcopyrite, and is characterized by pyrite-rich, brick-red, alteration halos in the monzonite. The ore zone is further constrained between two northeasterly striking, steeply dipping, 1 m wide shear zones that are filled with chlorite, quartz, and fragments of highly altered monzonite. The red alteration, which also occurs as patches in the monzonite farther away from veins, has been ascribed to hematization and may also include potassic alteration and silicification. The quartz-carbonate veins are infrequent in the basalts, although the same fracture systems are well developed. Those veins that do occur in the basalts, which include massive and pillowed textural varieties, have not visibly altered them.

The felsic intrusion at the Murphy-Garrison Deposit, again a quartz-poor monzonite, occurs only as dikes in the variolitic, feldspar-phyric and massive basalts. Three well developed sets of quartz-carbonate veins occur in the pit and each direction of veining corresponds to a strong fracture direction (Figure 2). The veins have light brown to gray, pyrite-rich alteration halos that contain the gold. Veins range from less than 0.5 cm to approximately 5 cm in width and the halos extend 2 to 10 cm on either side of a vein. Larger volumes of basalt have been altered where veins are closely spaced. The alteration apparently included silicification and carbonatization of the basalts, as well as the development of the pyrite. Unlike the Canadian Arrow Deposit, there are no observable features to distinguish different vein systems.

Discussion

The two deposits present interesting similarities and dif-

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ferences (Table 1). The mineralization in both is intimately related to pyrite that resulted from alteration. The alteration accompanied the emplacement of quartz-carbonate veins; this emplacement in both deposits was controlled by fractures in the host rocks. The host rocks to both deposits are basalts of the Kinojevis Group (Jensen 1974) that have been deformed and metamorphosed to greenschist grade, and a post-kinematic, quartz-poor monzonite. Gold mineralization did not occur until the intrusions were sufficiently solid to fracture in a brittle manner. At the Canadian Arrow Deposit, the alteration and mineralization occur in the intrusion; at the Murphy-Garrison Deposit, in the basalts. Although there is little monzonite present in the Murphy-Garrison Deposit (Figure 2), the large Garrison stock crops out less than 0.2 km from the pit and may be closer beneath the pit.

The stereograms in Figures 1 and 2 illustrate the important structural control of mineralization in these deposits. The upper stereogram in each figure is an equal area plot of poles to veins and the lower stereograms are equal area plots of poles to fracture surfaces. The different vein sets in the Canadian Arrow Deposit, defined by their attitudes and mineralogical and alteration characteristics, are represented by different symbols and the same symbols have been used in the stereogram of poles to fractures in order to demonstrate that the vein sets have been preferentially emplaced into different, pre-existing fracture sets. Although the veins in the Murphy-Garrison Deposit do not vary in their mineralogical and alteration characteristics, their attitudes do conform to those of the different fracture sets. Different symbols have been used for each of these dominant directions in Figure 2 to illustrate this structural control of the mineralization.

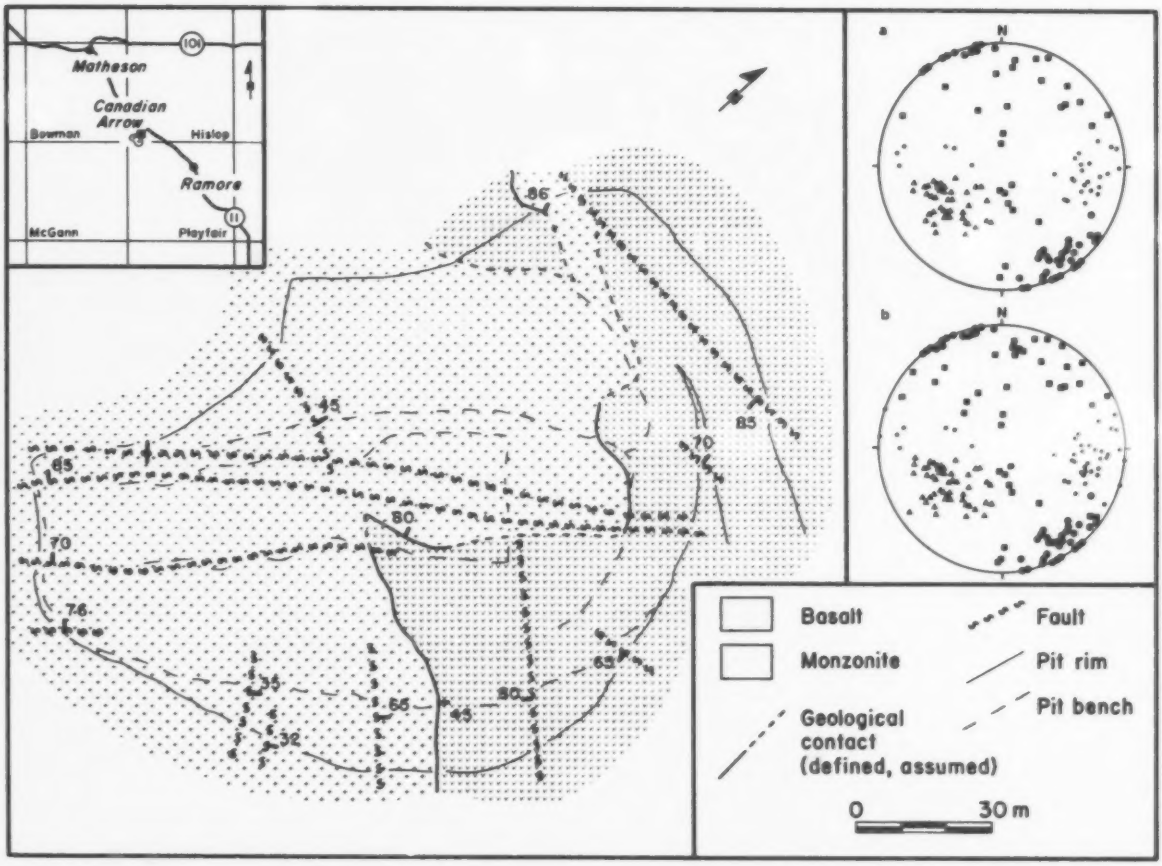

Figure 1—Location and geology of the Canadian Arrow Mine. The geological map is based on one by the staff of Pamour Porcupine Mines Limited and has been simplified for illustrative purposes. Stereograms are equal area plots of poles to (a) veins and (b) fractures. Orientations are represented by: triangles - vuggy veins with northeastern dips; large circles - steeply dipping veins with red alteration halos; small circles - veins with north-trending strike; squares - others.

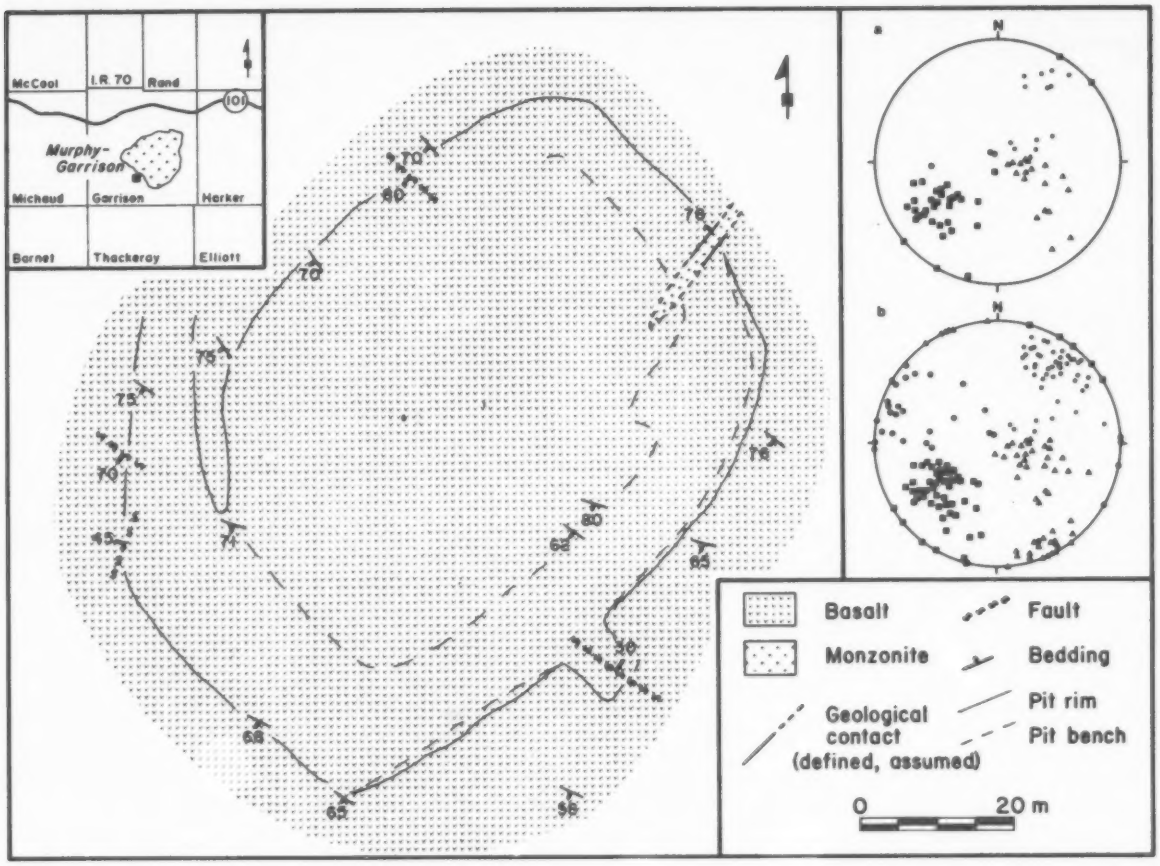

Figure 2—Location and geology of the Murphy-Garrison Mine. The geology has been simplified for illustrative purposes. Stereograms are equal-area plots of poles to (a) veins and (b) fractures. Vein directions are represented by: small circles - veins parallel to bedding; squares - veins with northeastern dips; triangles - veins with northwestern dips; large circles - others.

Future Research

The next steps in the program will include petrographic studies of the basalts and monzonites from both deposits to characterize the unaltered rocks and the alteration processes; whole rock and mineral chemistry to further characterize the alteration and mineralization processes, and, possibly, fluid inclusion and stable isotope studies of the veins and their alteration halos. These studies will, hopefully, contribute to determining the source of the vein material, the sulphide mineralization and the gold, the processes that led to formation of the deposits, and the timing of these processes.

Acknowledgments

Pamour Porcupine Mines Limited and Kerr Addison Mines Limited granted permission to examine and sample the deposits and made available information about them. Mr. P.C. Walford, Area Chief Mine Geologist for Pamour Porcupine Mines Limited in Timmins, was especially co-operative and enthusiastic in response to questions about the Canadian Arrow and other Pamour properties. Mr. Howard Lovell, Resident Geologist, Ontario Ministry of Natural Resources, Kirkland Lake, suggested examination of the Murphy-Garrison Deposit and was an invaluable source of information about the geology and mineral deposits of the area.

TABLE 1 CHARACTERISTICS OF THE CANADIAN ARROW AND MURPHY-GARRISON MINES

	CANADIAN ARROW MINE	MURPHY-GARRISON MINE
Major Lithologies (with mineralogy)	Kinojevis Group pillow and massive basalts. plagioclase + biotite + chlorite + epidote + minor pyrite) Monzonite. (plagioclase + K-feldspar + hornblende + chlorite + minor quartz + minor pyrite)	Kinojevis Group variolitic, feldspar-phyric and massive basalts (plagioclase + chlorite + hornblende(?) + minor epidote + minor pyrite)
Minor Lithologies	Recrystallized chert interflow horizon in basalts. Aplite dikelets in monzonite. Maroon, flow-foliated felsite dikes in basalts and monzonite.	Monzonite dikes in basalts. (plagioclase + K-feldspar + chlorite + minor quartz + minor pyrite) Recrystallized chert interflow horizons in basalt. Boudinaged quartz-garnet-epidote veins in basalts
Structures	Basalts foliated parallel to layering. All lithologies highly fractured. Chert horizon deformed to a mylonite with isoclinal intrafolial folds. Two 1 metre wide, sub-parallel major shear zones in monzonite, filled with quartz + chlorite + fragments of altered monzonite.	Basalts foliated parallel to layering. All lithologies highly fractured.
Alteration and Veining	Quartz-carbonate veins dominantly in monzonite. Vein sets defined by fracture directions: 1)NE dips – oldest, vuggy, contain galena, lack halos. 2) NE strikes – youngest (?), have brick-red alteration halos. 3) N-S strikes – occur with and without red halos. 4) Others – less regular orientations, occur with and without red halos. Few veins in basalts; no alteration halos in basalts. Alteration includes silicification, pyritization, and hematization and/or potassic alteration.	Quartz-carbonate veins in basalts. Vein sets defined by fracture directions: 1) NE dips. 2) Parallel to layering in basalts. 3) NW-dips. 4) Others – less regular orientations. All vein sets may have alteration halos. Alteration includes silicification, carbonatization and pyritization.
Mineralization	Gold intimately associated with pyrite. Pyrite developed in alteration halos around quartz-carbonate veins. Mineralization restricted to monzonite and largely between two major shear zones.	Gold intimately associated with pyrite. Pyrite developed in alteration halos around quartz-carbonate veins. Mineralization occurs in basalts.

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No. 26 Alteration, Metamorphism, and Structure Associated with Archean, Volcanic-Hosted Gold Deposits: Preliminary Observations in the Red Lake District

A.J. Andrews[1]

Introduction

During the summer of 1982, field mapping and sampling were conducted in the Red Lake gold district. This marks the initiation of a multi-year project to study the nature of alteration, metamorphism, and structure associated with Early Precambrian (Archean), volcanic-hosted gold deposits in Ontario. This investigation is to be approached as a field oriented, petrological-geochemical study and is complementary to other studies on gold recently initiated by the Mineral Deposits Section.

Appreciation of the nature of alteration associated with gold mineralization can potentially reveal fundamental aspects concerning the mechanism of ore genesis, the process of metal transport, and the history of ore deposition, and also aid in the identification of lithogeochemical characteristics useful in exploration. Appreciation of structural elements associated with gold is essential, since in most deposits structural control is of central importance in the localization of ore.

The goals of this study are:

1. to establish the history of alteration/metamorphism in host rocks and country rocks of each selected deposit (district scale) and to identify the processes involved (e.g. synvolcanic-seawater systems; intrusion related systems; regional metamorphic dehydration)
2. to identify the timing of mineralization with respect to the history of alteration
3. to identify the role of host-rock lithology in ore deposition
4. to establish a classification of alteration types with respect to the various gold deposit types
5. to assess the relative potential of different alteration processes to concentrate gold ore
6. on the basis of the above, to contribute to the production of a comprehensive metallogenetic model for gold ore formation and the generation of lithogeochemical guides to exploration

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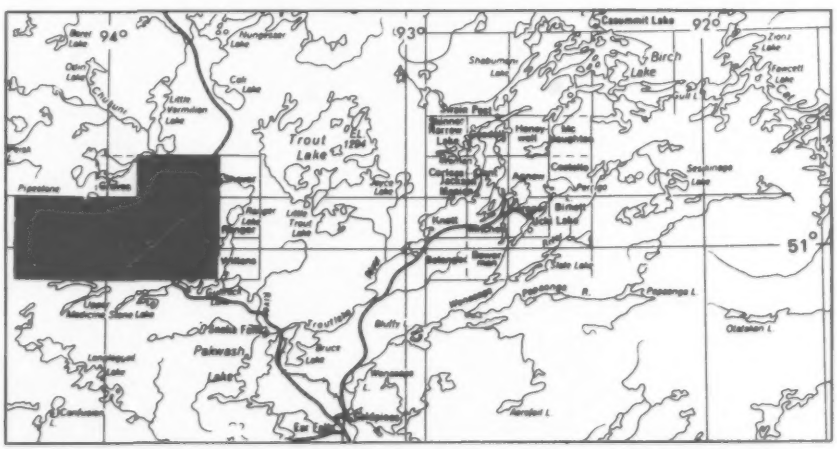

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

Studies in the Red Lake Camp

Selection of the Red Lake gold camp as the initial study area was based on two factors. Firstly, it was considered necessary and timely to emphasize 'district scale' as opposed to 'deposit focussed' studies on gold. Most recent studies on gold have been deposit focussed and, while this approach provides valuable, detailed information concerning individual deposits, comparatively little information is available concerning the relationship of gold mineralization to regional patterns of structure, stratigraphy, and alteration.

Secondly, the Red Lake camp has recently been the focus of detailed (1:12 000) mapping (Pirie and Sawitzky 1977, Pirie and Grant 1978a, 1978b), regional stratigraphic and structural synthesis (Pirie 1981, Wallace 1980, 1981), geochronological studies (Thurston *et al.* 1981), and studies of individual mines (Rigg and Helmstaedt 1981, MacGeehan and Hodgson 1981, Kerrich *et al.* 1981). With this comprehensive data base the Red Lake volcanic belt lends itself well to a district scale study on the metallogeny of gold.

For the initial phase of this study, emphasis is being placed on the eastern part of the belt (McDonough, Bateman, Dome, and Balmer Townships) in the general vicinity of past and present producing mines (Figure 1). Observations by Pirie (1981) and Wallace (1980, 1981) suggest that the volcanic-sedimentary rocks in this area may be disposed in a regional scale antiform, a structure possibly related to the intrusion of a large granitic body located to the east (Figure 1). At present details of this complex structure are not well known. Pirie (1981) has recognized the existence of a 'highly altered zone' (HAZ) which is coincident with many of the past and present producing mines and is superimposed on a background of pervasive greenschist grade volcanic-sedimentary rocks which underlie most of the area. The HAZ is characterized by a highly complex pattern of alteration and structural features. Its history, relationship to the surrounding country rocks, and significance to gold mineralization are not well known.

Initial Field Observations

During this summer, mapping and sampling were conducted in the background, greenschist grade volcanic-sedimentary rocks and in parts of the HAZ, with emphasis on the former. In the HAZ detailed mapping and sampling were conducted on the Marcus and Wilmar East Properties (Wilanour Resources) and the Redcon Property (Dickenson Mines)(Figure 1). As the study progresses, emphasis will gradually shift to the highly altered, mineralized areas.

The following is a summary of observations resulting from the past summer's work.

Volcanic Rocks Outside the HAZ

1. The majority of rocks outside the HAZ are of greenschist grade, consisting of fibrous amphibole, chlorite, carbonate, occasional epidote, and rare garnet. Ultramafic extrusive rocks are often actinolite-rich, while ultramafic intrusive rocks, such as the East Bay peridotite, are usually serpentinized to varying degrees. The causative processes for these alteration types will be determined from field, petrographic, and geochemical data, including stable isotope geochemistry and possibly, alteration dating.

2. Amphibolite grade metamorphic rocks constitute a relatively wide band (up to 2 km in width) adjacent to the granite batholith in Bateman and Balmer Townships. The extent of contact metamorphic effects beyond the amphibolite grade rocks is not yet known; however, in the surrounding greenschist grade terrain biotite becomes increasingly more abundant as the amphibolite zone is approached. The amphibolite grade rocks consist predominantly of hornblende and plagioclase with occasional garnet.

   West to southwesterly dipping contacts and foliations in the volcanic units adjacent to the granite mass may reflect a west to southwesterly plunging volcanic-granite contact. This would be consistent with the relatively wide contact metamorphic aureole observed in Balmer and Bateman Townships, and may have significance with respect to structure and gold mineralization in the vicinity of the active mines, located to the southwest.

3. In detail, the study area is structurally complex; however, in a regional sense the volcanic rocks outside and within the HAZ appear distinct with respect to their styles of deformation. In the former it is predominantly ductile, while in the latter (described below) it is of a more brittle nature.

   Ductile deformation outside the HAZ manifests as pillow elongation, boudinage, the development of penetrative foliation, and shearing. The degree of flattening increases as the easterly granitic body is approached, with the most intense deformation forming a zone approximately 1 km wide adjacent to the volcanic-granite contact. Within the volcanic pile discrete zones of shearing occur parallel to lithological contacts and preferentially along contacts separating rock units of contrasting competency. In this respect, mafic volcanic units tend to be sheared where they are in contact with massive gabbroic and ultramafic sills, the latter tending to maintain their structural integrity. These zones of shearing are best observed along shoreline exposures in east McDonough, west Bateman, and Dome Townships, an area which comprises the northwest limb of the regional antiform discussed above. Relative movement between units of different competency would be expected along the limbs of a fold.

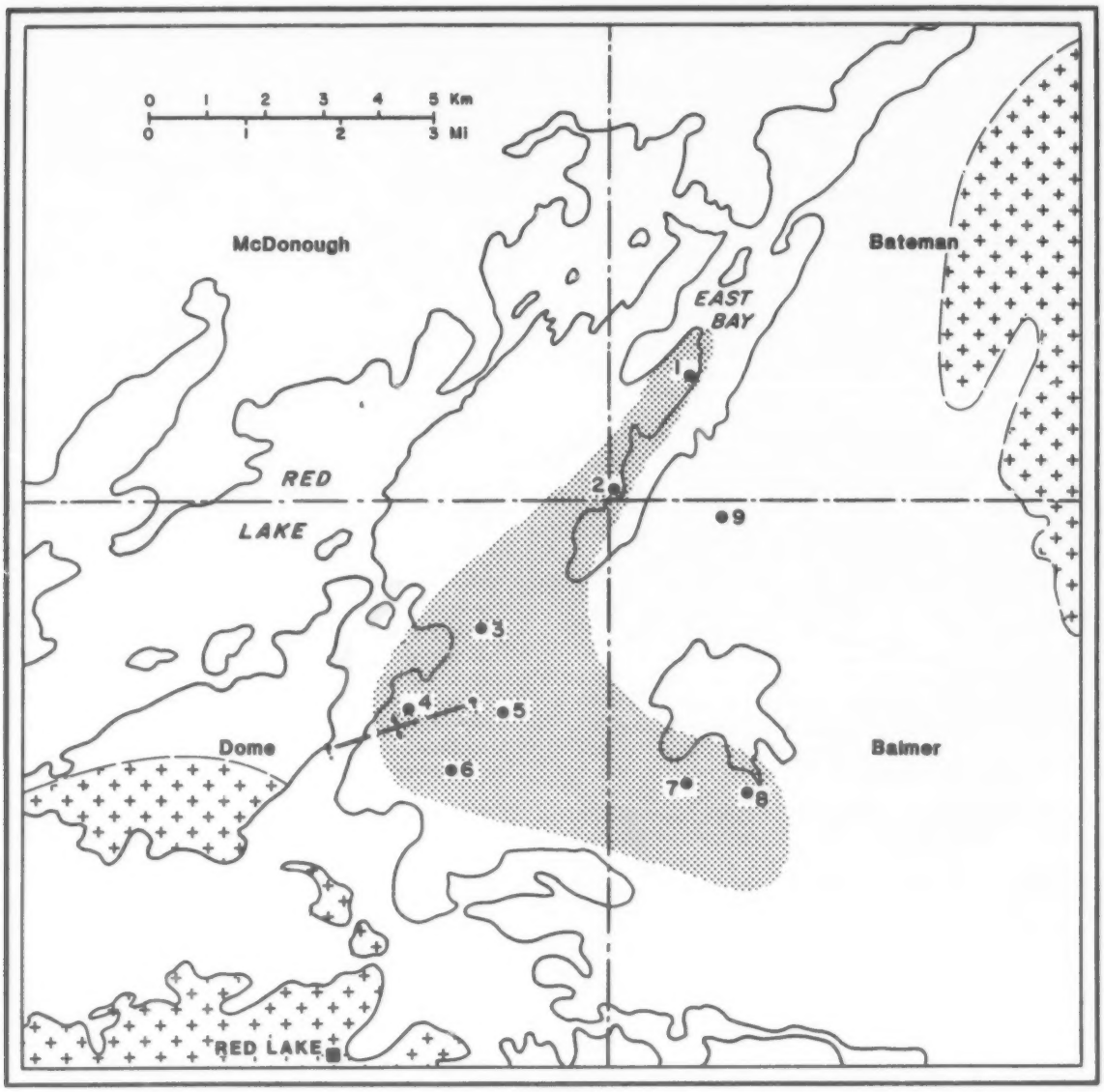

Figure 1—The Red Lake study area (after Pirie 1981).

4. Carbonate minerals are pervasive throughout the volcanic-sedimentary belt. Iron carbonates (mainly dolomite), predominate in the HAZ (see below) whereas calcite predominates in all the surrounding areas. Most lithologies in the eastern part of the belt contain 2 to 10 modal percent calcite. It occurs preferentially along structural features in the rock, particularly the regional foliation and shear planes described above. In this respect, the calcite appears to be a late alteration event which postdated establishment of the pervasive greenschist mineralogy, and was either contemporaneous with or postdated the generation of the major fold structure. Iron carbonates (mainly dolomite) also occur in these rocks, but appear to be restricted to the lithologically controlled shear zones. These carbonatized shear zones are restricted in width (<15 m), but extend up to kilometres in length. They are generally parallel to stratigraphy and contained within relatively incompetent basaltic units. Across shear zone boundaries the iron carbonate alteration abruptly decreases in intensity and within a few metres calcite predominates in the surrounding country rocks.

Rocks within the HAZ

1. The highly altered zone (HAZ) is distinct from the surrounding greenschist grade rocks with respect to alteration and deformation. The shape of the HAZ, as observed by Pirie (1981) and confirmed by the author, appears to reflect the general shape and orientation of the regional antiform (Figure 1). As such, the HAZ resembles, at least in form, a saddle reef structure. The boundaries of the HAZ seem to be well defined, the transition from greenschist to highly altered rock occurring over a width of less than 300 m. As yet, the boundary itself has not been observed in outcrop.

2. The rocks of the HAZ exhibit at least three distinct alteration types: silicification, carbonatization, and sericitization. This order of listing may be temporally significant from relatively early to late. Silicification, which is rather patchy in its distribution, is the least common of the three alteration types and results in significant bleaching and hardening of the rock. The silicification has occurred via pervasive addition of SiO_2 rather than the generation of numerous quartz veins. The HAZ is most characterized by intense, relatively pervasive iron-carbonatization (dolomite ± calcite). This manifests as discrete carbonate veinlets, intense stringer systems, massive carbonate veins (centimetres to metres in width), and pervasive carbonate addition to the massive rock. The addition of such large quantities of carbonate has rendered the rocks (mainly basalts) relatively brittle and highly amenable to fracture, a factor which may be significant with respect to localization of gold mineralization. Sericitization appears largely, though not exclusively, lithologically controlled. It occurs, for the most part, in felsic rock types; however, certain parts of pillow basalt units also appear sericitized. Ultramafic intrusive bodies which extend from the surrounding country rocks into the HAZ exhibit important changes in alteration across this boundary. In the former, they are moderately to highly serpentinized. In the latter, the serpentine alteration is often overprinted by extensively carbonatized and talcose (± fuchsite) shear zones that occur within and along the contacts of the intrusive body.

3. Structurally the HAZ is characterized by two prominent features. Brittle deformation takes the form of intense fracturing, small scale faulting, and numerous zones of predominantly simple shear. This brittle deformation may be a function of inherited competency, resulting from the pervasive carbonatization of these rocks, as described above. The second feature is a persistent fracture cleavage developed at 120° and best observed in the southern part of the HAZ in Dome and Balmer Townships. This fabric appears to be post-carbonatization, in that it is axial planar to folded iron-carbonate veins.

4. Gold mineralization observed on the Marcus, Redcon, and Wilmar East Properties is relatively late in the metamorphic/structural history of the area. It occurs in quartz ± tourmaline vein systems which cross-cut most of the other structures. These veins occur in most rock types, particularly the highly carbonatized areas which, due to their inherited competency, have been intensely fractured. It is common for gold to occur in quartz ± tourmaline stringers which cross-cut massive, iron-carbonate veins. These observations indicate that introduction of gold was, at least in part, post-carbonatization.

5. The majority of important past and present producing mines in the area are distributed along distinct structural trends. The Cochenour Mine occurs close to the hinge of the proposed antiform and is aligned on its northwest limb, parallel to stratigraphy, with the McMarmac, Abino, and McFinley Mines (Figure 1). On the southeast limb, the Cochenour Mine appears aligned along the same structural trend as the Wilmar East Property, the Campbell Mine, and the Dickenson Mine. The significance of this pattern, together with the saddle reef form of the HAZ must await further study.

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No. 27 Geology of the Madsen Gold Area, Red Lake

Marcel E. Durocher[1] and Steven van Haaften[2]

Introduction

Field work during 1982 consisted of detailed mapping (1:5000) in the vicinity of the Madsen and Starratt-Olsen former gold producers in Baird Township. The objectives of this study are to outline and characterize the alteration haloes associated with these deposits and determine if there are any correlations between gold mineralization and geochemical anomalies within the ore horizon.

General Geology

The general geolcgy of the Madsen area is shown in Figure 1. The rocks in this area can be grouped into two major sequences; a lower tholeiitic-komatiitic sequence, and an upper calc-alkalic sequence (Pirie 1981; Wallace 1981). The two sequences are part of the southeast-facing, southern limb of a large fold or dome structure centred to the north of the study area (Wallace 1981). The strike and dip of the rock units in both sequences varies systematically across the study area, defining a large, open, S-shaped flexure. In the vicinity of the Starratt-Olsen Mine (southwestern part of the area), the units strike 055 to 060° and dip 70°SE. In the central part of the area, close to the Madsen Mine, the strike is 030° and the dip is 65°SE. One kilometre northeast of the Madsen Mine the strike is 045° and the dip is 70 to 75° SE. Foliation in the area generally strikes 045 to 050° and dips 70 to 75° SE.

The tholeiitic-komatiitic sequence consists mainly of tholeiitic pillowed basalts, with subordinate amounts of basaltic komatiitic and komatiitic flows and flow breccias. Thin (2 to 15 m) interflow tuff units occur in the upper part of the sequence.

The calc-alkalic sequence consists mainly of spherulitic felsic flows with lesser amounts of intermediate to felsic tuffs and tuff-breccias. Thin (15 to 250 m) units of mafic to intermediate pillowed flows and pillow breccia also occur within this sequence.

The Austin Tuff, which is host to all of the mined gold in the area, is located along the contact between the two major rock sequences. It varies in thickness from 10 to 100 m and has been traced along strike for 9 km. It is composed of interlayered tuff and tuff-breccia beds. Thin mafic and ultramafic flows occur in the lower part of this unit. At present, it is unclear whether these rocks should be included in the tholeiitic-komatiitic sequence or the calc-alkaline sequence.

Numerous gabbro sills and dikes are present within both sequences, and appear to be related to the calc-

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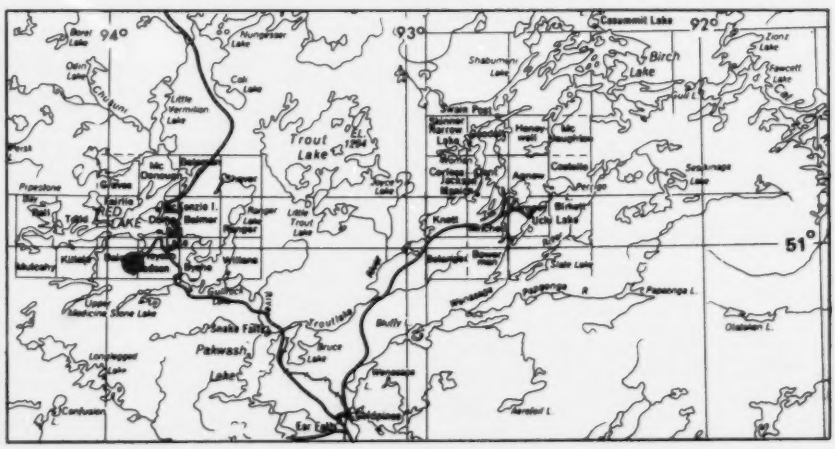

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

alkalic volcanism. The youngest rocks in the area are the granodiorite rocks of the Faulkenham Lake Stock and the Killala-Baird Batholith.

Preliminary results of petrographic studies indicate that the volcanic and mafic intrusive rocks in the area have been subjected to amphibolite facies regional metamorphism, and at a later period to contact metamorphism associated with intrusion of the Faulkenham Lake Stock and the Killala-Baird Batholith.

Economic Geology

To date, all gold production has come from the Austin Tuff. However, anomalous gold values also occur in the tuff and tuff-breccia units located in the upper part of the tholeiitic sequence and the lower part of the calc-alkaline sequence.

Ore zones are stratabound within the Austin Tuff and occur where this unit exhibits significant increase in apparent thickness. These zones comprise several *en echelon* ore bodies, contained within irregular lenses of highly foliated altered tuff (Horwood 1940). While the ore zones are oblique to the foliation, the individual ore bodies parallel foliation in the surrounding rocks.

Hydrothermal Alteration

Field observations and preliminary petrographic studies indicate that there is an extensive hydrothermal alteration halo associated with the Madsen and Starratt-Olsen gold deposits. This alteration halo extends along strike to the northeast for at least 9 km. It is not confined to the Austin Tuff but extends outward for 0.5 to 1 km into the surrounding tholeiitic-komatiitic and calc-alkaline sequences. As a whole, the alteration halo is characterized by the presence of ubiquitous, finely disseminated carbonate and biotite. The Austin Tuff also contains variable proportions of muscovite, andalusite, cordierite, staurolite, and almandine garnet. While these minerals were recognized by Horwood (1940) and Ferguson (1965), they did not relate them to the larger alteration halo. Pirie (1981) suggested that the aluminous assemblages observed in the Austin Tuff may be due to sodium depletion during hydrothermal alteration. Wallace (1981) interpreted the Austin Tuff as being metasomatized intermediate pyroclastic rock. The distribution and proportions of potassium-bearing phases and carbonate in the rocks of the study area strongly suggest that there has been potassium and CO_2 metasomatism associated with the formation of these gold deposits.

The relative timing of hydrothermal alteration can be

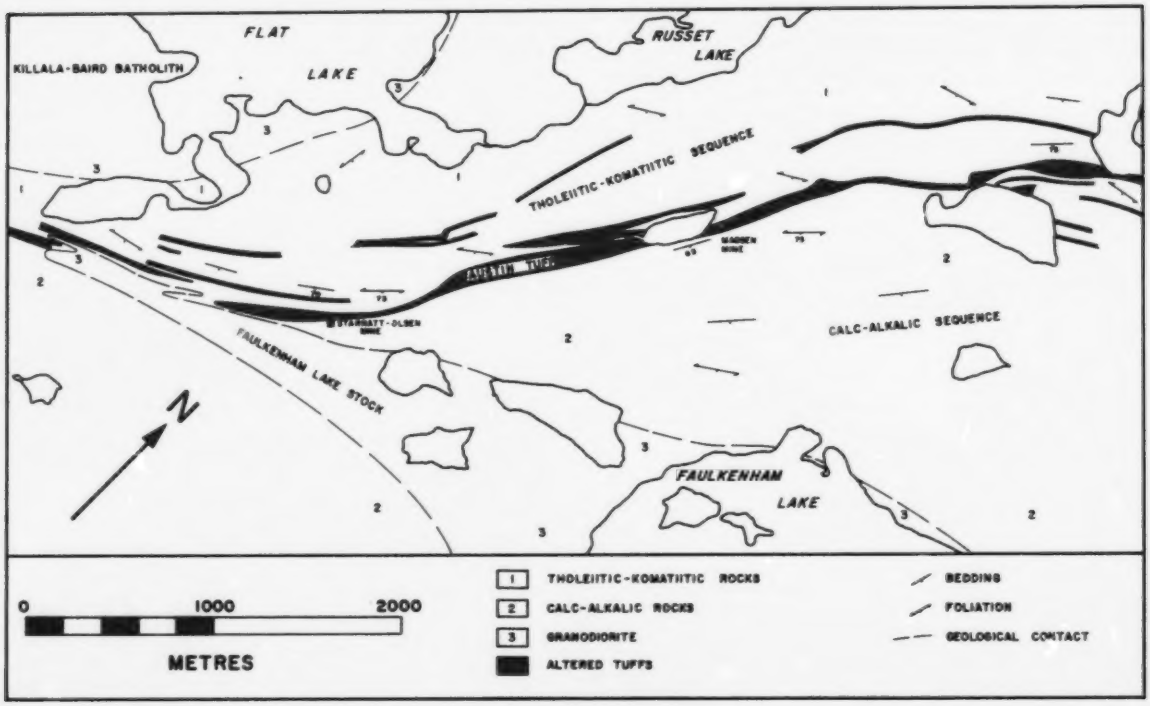

Figure 1—General Geology of the Madsen Area, after Horwood (1940) and Ferguson (1965).

readily bracketed. Both the tholeiitic-komatiitic and calc-alkaline sequences are altered, as are the gabbro dikes cutting these units; alteration was therefore syn- or post-dike intrusion. The present mineral assemblage in the altered rocks is the result of thermal or contact metamorphism of previously altered rocks; alteration therefore predated the intrusion of the Faulkenham Lake Stock and Killala-Baird Batholith. The timing of alteration relative to regional metamorphism has not been defined.

Discussion

This work has highlighted several geological features which are consistently associated with the gold mineralization in this area:

1. The gold mineralization is stratabound within a well defined volcanic stratigraphic succession with a strike length of at least 9 km. Gold showings are largely restricted to the more felsic tuff units and to date, economic concentrations have been located only within the thicker Austin Tuff.
2. The contact between the tholeiitic-komatiitic and calc-alkaline sequences represents a major stratigraphic break and possibly a significant structural break of a strike-slip nature. The main gold host, the Austin Tuff, lies consistently along the contact zone of the two main sequences. The Howie and Hasaga former producers are located 12 km to the northeast along the strike extension of this postulated structural zone.
3. The gold mineralization consistently lies within a zone of highly altered rocks. The alteration zone is elongate northeast-southwest and affects both major volcanic sequences.

The continuing work on this area will better document the geological associations of gold in this area and attempt to define the processes responsible for gold concentration.

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No. 28 The MacLeod-Cockshutt and Hard Rock Mines, Geraldton: Examples of an Iron-Formation Related Gold Deposit

A. James Macdonald[1]

Introduction

The spatial association between gold deposits and Precambrian iron formations has been widely recognized for at least half a century (Boyle 1979). The association is most marked in Early Precambrian (Archean) "greenstone belts", such as the Kolar goldfield in the Mysore Plateau Dharwar metavolcanics of India (Narayanaswami *et al.* 1960), over 125 deposits in the Sebakwian Group of Zimbabwe (Fripp 1976), in Early Precambrian banded iron formation near Jardine, Montana, U.S.A. (Hallager 1982), the Central Patricia and Pickle Crow Mines in the Crow River District of Ontario (Barrett and Johnston 1948; Corking 1948), and the MacLeod-Cockshutt and Hard Rock Mines south of Geraldton, Ontario (Ferguson 1967). Precambrian (possibly Early Precambrian) iron formation related gold deposits include the Homestake Mine in South Dakota, U.S.A. (McLaughlin 1931), similar deposits near Contwoyto Lake in the Northwest Territories, Canada (McConnell 1964), several mines in the 'Quadrilatoro Ferrifero' of the Minas Gerais District, Brazil (Matheson 1956), The Mount Magnet, Lennonville, and Bougardi Deposits of Western Australia (Lambert *et al.* 1982; Finnucane 1953), and the Geita and Musoma Goldfields of Tanzania (Harris 1961; Basu 1982).

Two possible genetic models have been proposed for gold lodes in general, and are applicable to the iron formation association:

1. the "magmatic differentiation theory", which maintains that gold is derived from a crystallizing magmatic body, concentrated in a siliceous, hydrothermal fluid, and injected into a structurally prepared host rock
2. the "metamorphic secretion theory" which suggests that the associated lithologies, such as iron formation, were the metal source, or protore, from which the gold was mobilized and concentrated as a result of regional metamorphism (Saager and Meyer 1982)

In an attempt to investigate this topic, work com-

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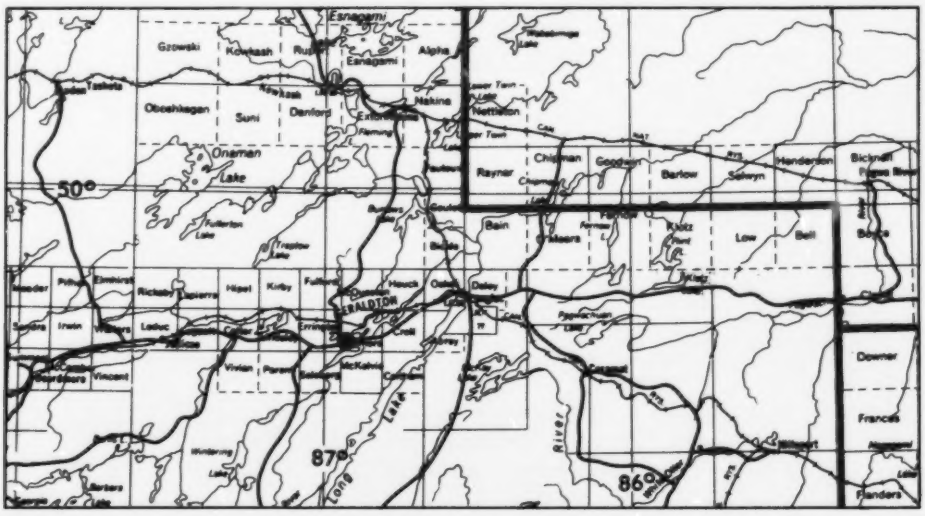

LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles

menced in 1982 on the MacLeod-Cockshutt and Hard Rock Mines, in the Wabigoon "Greenstone Belt", 5 km south of Geraldton. The mines are located in Ashmore Township, mapped by Horwood and Pye (1955). Both mines (and the Consolidated Mosher Mine immediately to the west) worked the 4.7 km strike extensions of several ore zones. All three mines are owned by Lake Shore Mines Limited. Both mines commenced production in 1938 and, apart from brief closures in late 1945 and early 1946 due to labour shortages, were in steady production until the Hard Rock closed in 1951 and the MacLeod-Cockshutt in 1970. The Hard Rock Mine produced 269 081 ounces of gold, and the MacLeod-Cockshutt 1 475 728 ounces.

Preliminary Work

Clays deposited in the last 20 years were removed to facilitate examination of an open stope (Glory Hole, Figure 1) near the boundary between the two properties. A 90 m by 50 m grid was surveyed over the Glory Hole using back site and chain, enabling construction of a base map showing the Glory Hole perimeter. The map was supplemented by low altitude (150 m) aerial photographs.

Structure and Lithology - Preliminary Results

The north ore zone is located in a 'Z' shaped dragfold on the north limb of the approximately west-northwest-striking Hard Rock Synclinorium (Ferguson 1967, Section 1). The synclinorium is located in the footwall of a major break, the Bankfield-Tombill Fault. Indicated motion of the fault is dextral strike slip. Both the major and minor fold structures and the contained ore zone plunge to the west at between 28° and 29° (Horwood and Pye 1955).

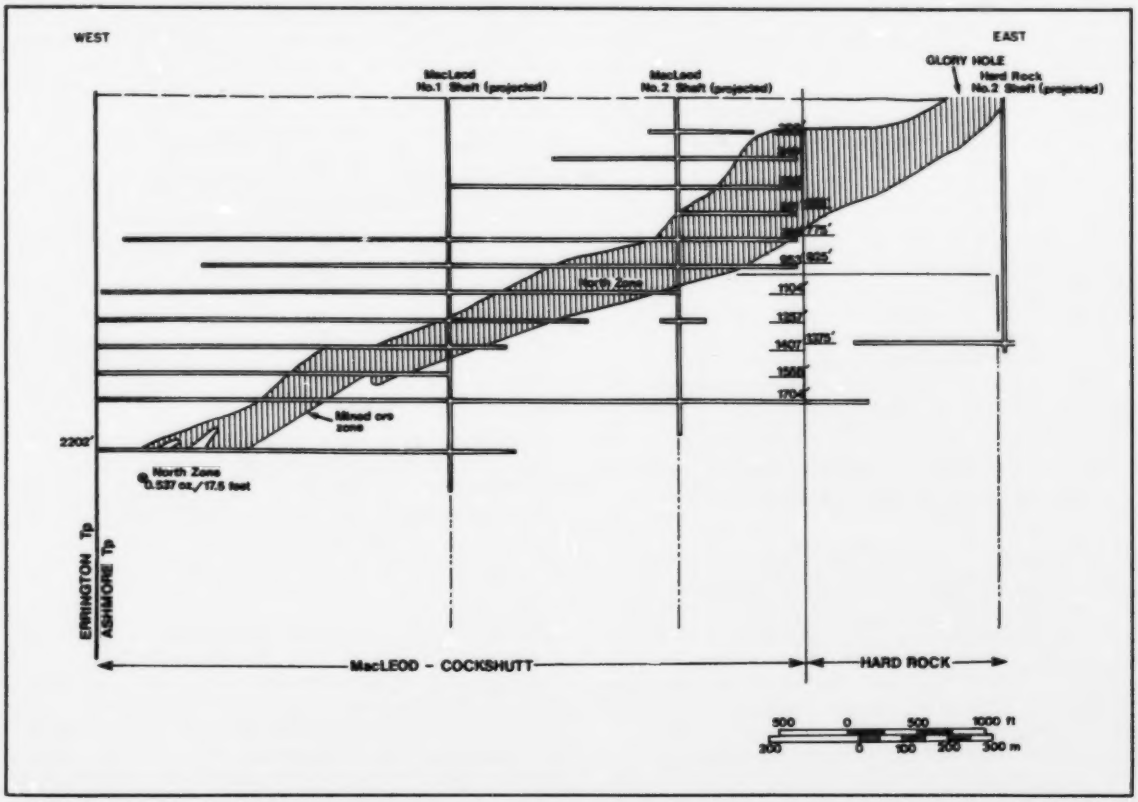

Figure 1—Cross-section of the North Zone, MacLeod-Cockshutt, and Hard Rock Mines, Geraldton, Ontario. The gold mineralization is associated with iron formation.

Four prominent lithologies are exposed in the Glory Hole:

1. banded iron formation
2. metasediments, principally siltstone and wacke
3. porphyry sills
4. felsite sills and dikes

The banded iron formation consists of three subunits:

1. lean iron formation: discrete beds of magnetite (typically up to 1 cm thick) in wacke and siltstone
2. magnetite iron formation: alternating beds (typically 1 cm) of magnetite (with minor hematite) and silicified mudstone or dark chert
3. magnetite/jasper iron formation: alternating 1 cm beds of magnetite and jasperitic quartz or red chert

All subunits may, in addition, contain varying amounts of iron-bearing carbonate.

The metawacke and metasiltstone show gradational contacts with both the northern and southern flanks of the iron formation. The rocks are locally carbonate rich and structurally disturbed. Considerable shear strain has been localized by the finer grained material, disrupting and rafting apart metawacke horizons and resulting in an intraformational breccia: the resulting rock contains apparently randomly distributed, but uniformly aligned, clasts of metawacke (typically 5 cm in long dimension, but up to 50 cm) in metasiltstone. All primary bedding is frequently destroyed; the principal planar feature is a shear-related cleavage.

The porphyry sills rarely exceed 1 m in thickness, and are feldspar-phyric with minor quartz phenocrysts. The feldspar is altered by chlorite and sericite. Although concordant on a large scale, in detail the porphyry sills cut sedimentary contacts and may possess chilled margins up to 10 cm in thickness. The felsite intrusions (very fine grained), which are similar to the matrix of the porphyry sills, may be concordant, or may cut sedimentary contacts at angles of up to approximately 40°.

On an outcrop scale, extensive folds are present within the iron formation and porphyry units, with amplitudes up to 5 m. Fold axes are sub-parallel to the main synclinorium axis. The folds all exhibit a Z-fold style, reflecting on a smaller scale the drag fold in which the ore body is located. Shear zones, up to 1 m in thickness, and sub-parallel to fold axes, are commonly located along the porphyry-iron formation and metasediment-iron formation contacts but may also cut across stratigraphy in the iron formation. Where evidence is unequivocal, dextral shear is indicated. On a hand specimen scale, extremely delicate kink structures are present in the iron formation in response to the drag folding event. Feldspar phenocrysts in the porphyry sills are stretched parallel to the fold axes and direction of the shear. This foliation remains unaffected by the outcrop-scale folds, suggesting that final penetrative shear post-dates final folding.

Mineralization

Metal and metal sulphide mineralization are found in three structural types:

1. relatively undeformed quartz-carbonate-sulphide veins striking approximately west-northwest, often localized by shear faults
2. deformed quartz-carbonate-sulphide veins, striking obliquely (east-northeast) to the major structures
3. quartz-carbonate-sulphide replacement ore after iron formation, spatially associated with type '1' veins

The mineralogy of all three types is essentially identical. Gangue mineralogy includes quartz-ankerite-calcite-tourmaline-scheelite and a green sheet silicate (possibly a chromium-rich mica). In addition to pyrite, other sulphide minerals present, in decreasing order of abundance, are arsenopyrite, pyrrhotite, sphalerite, chalcopyrite, and galena.

Type '1' veins locally comprise a sheeted vein system of subparallel veins (striking west-northwest and dipping steeply northwards) with vein frequency reaching 4 or 5 per metre. Typical vein widths vary between 2 and 10 cm. In the Glory Hole, sheeted veins are located solely within the porphyry unit. Where the sills are thickened in fold hinges, widths up to 7 or 8 m are attained. The sheeted veins commonly terminate at contacts with enclosing iron formation.

Types '1' and '3' ore are apparently unaffected by folding, indicating generation of the structures after folding. Type '2' veins and veinlets, which strike obliquely to the other veins, are often highly folded due to approximately west-northwest shear, producing shortenings of considerable magnitude (e.g. a type '2' vein may be attenuated by up to 80 percent of its original strike length by tight isoclinal folding in response to shear within the host rock). These structures have led Horwood and Pye (1955) to refer to type '2' veins as "wiggly" veins. The same veins are seen throughout the McLeod-Cockshutt and Hard Rock Mines.

Relative ages of the three vein types are equivocal. Type '2' veins are seen to both cut and be cut by mineral selvages in type '1' veins. Both may be displaced by type '3' shear-related structures, although this motion may only reflect late stage adjustment along shear planes.

Summary

Gold-bearing mineralization associated with iron formation on the MacLeod-Cockshutt and Hard Rock Properties is found in both quartz veins and as replacement of the sediment. The ore-bearing structures are controlled by lithological contacts and localized strain deformation. Structural analysis of vein, shear, and fold axis attitudes will permit confirmation of the field impression that all three are related to the three-tier structural hierarchy:

1. Hard Rock Synclinorium

2. North Zone drag fold

3. minor drag folds

The iron formation host rock may have been the original gold source, or protore (Saager and Meyer 1982). To test this theory petrologic and trace element analysis of iron formation through the region will be studied to detect any changes in mineral or chemical composition in the vicinity of known mineral deposits.

Detailed petrography will reveal the sequence for mineralization stages in the vein/shear structures and which stage(s) introduced gold. Microthermometric and isotopic analysis of fluid inclusions from the auriferous stage(s) will aid in determining:

1. the temperature of ore formation

2. the ambient physical conditions during ore formation

3. the composition of the mineralizing fluid

4. the affinity of the fluid responsible for mineralization, be it magmatic, meteoric or metamorphic

Once a model for gold ore genesis related to iron formation has been developed for the Geraldton area its applicability will be tested on other deposits, such as those in the Crow River District.

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No. 29 Gold Deposits of the Abitibi Belt, Ontario

C.J. Hodgson[1]

Introduction

Very few major gold discoveries have been made in northeastern Ontario since the early decades of this century when this part of the Canadian Shield was first systematically prospected. This is in contrast to the exploration history of copper-zinc massive sulphide deposits, the most economically important of which were found in overburden-covered areas by geophysical prospecting methods in the last 20 years. A ratio of exposed to covered gold deposits similar to that of massive sulphides might be expected and, hence, there should remain, in Ontario, many undiscovered good gold deposits.

Prospecting for gold in areas of covered ground is both technically difficult and expensive, however, and it is therefore logical to spend considerable time and effort in choosing the best possible target areas on the basis of existing geological data before initiating exploration on the ground. One of the major problems with the existing data on gold deposits is that it is not in a form which allows a geologist to readily determine the nature of the deposit population, either from a geological or an economic point of view. Particularly relevant to the problem of exploration area selection are the questions: What are the geological differences, if any, between economically better and economically poorer deposits? Is it possible to define anomalously mineralized areas (mining camps), independently of "exploration intensity" or "percent exposure", using parameters such as the ratio of economically better to economically poorer deposits, the incidence of certain assemblages of rocks or ore-associated minerals, or the incidence of alteration types in the gold prospects? How common (and thus important in geochemical exploration) is the association of gold with minerals like tourmaline, scheelite, and arsenopyrite? Are there any as yet unrecognized spatial relationships between gold mineralization and particular rock types? How common, and thus significant in exploration, is the association of gold deposits with rock types like iron formation?

The present project was initiated in order to investigate these and related problems. It has involved the generation of a file containing data, in machine processable form, on the geological and economic characteristics, extent of physical exploration, location, discovery date and method, and selected other data on the known gold deposits in the area covered by Ontario Geological Survey, Compilation Map 2205, Timmins-Kirkland Lake Area (Pyke *et al.* 1973). Data for 725 deposits was entered in the file. A thorough review was made of the general geological relationships in the area as these relate specifically to gold mineralization, and because all of the reports and maps concerned with the area had to be examined in detail in the course of the project in order to locate the data for the file. The file format was designed and the coding was done in the period November 23, 1981, to July 1, 1982. About 3 weeks were spent in the field during the summer to examine key areas. The interpretation of the results and preparation of an Open File Report are in progress. The Open File Report will present in detail a regional geological review, and some of the preliminary results of compilation and comparison of data within the file. Some of the major results of the study are noted herein.

The original concept of the project was proposed to the Ontario Geological Survey by the author while associated with the Mineral Exploration Research Institute, McGill and Ecole Polytechnique Universities, Montreal. The project was carried out as a research contract awarded to that Institute.

Regional Geological Compilation

The objective of this part of the study was to define the relationship, if any, of gold deposits to large scale lithostratigraphic assemblages and/or structures.

The main geological features of the area are interpreted to have formed in a dominantly extensional tectonic regime. The deformation style in this regime could result from either of two processes: large amounts of extensional strain (~ 100 percent) associated with volcanism and syn-volcanic sedimentation in an intercratonic environment (Proffett 1977), or listric normal faulting, a form of normal faulting on upward concave fault planes that results in the rotation of bedding into steep attitudes such that beds face in the direction of the surface expression of the fault on which they are rotated (Proffett 1977). The listric normal fault hypothesis provides a rational and internally consistent explanation for many of the enigmatic features of "greenstone belts" in general, and the area covered by Map 2205 in particular, as shown in Table 1. It has been accepted by the author as the deforma-

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TABLE 1 CHARACTERISTICS OF THE ABITIBI GREENSTONE BELT IN THE TIMMINS-KIRKLAND LAKE AREA AND THEIR INTERPRETATION IN LIGHT OF THE LISTRIC NORMAL FAULT HYPOTHESIS

CHARACTERISTIC	INTERPRETATION
Very large apparent stratigraphic thicknesses	Fault repetition of a section of normal thickness
General low metamorphic grade	Section is of normal thickness
Consistent facing of large structural domains	Steep dips are due to rotation on faults
Presence of local angular unconformities	Sedimentation and volcanism continued during extension and rotation
Unreasonably (?) abrupt facies changes	Fault contacts
Limited depth extension indicated by gravity surveys (Gupta *et al.* 1982)	Steep dips are due to rotation of normal faults

tion mechanism operative in the Timmins-Kirkland Lake area. This hypothesis also explains the fact that major stratigraphic contacts within "greenstone belts" are very commonly broadly parallel to the external contacts of the belt with the enveloping granitoids if it is assumed that the "greenstone" assemblages were deposited on sialic crust and that the outer contacts of "greenstone belts" are the unconformable base of the "greenstone" sequence, more or less modified by subsequent, metamorphically induced remobilization.

Within the Timmins-Kirkland Lake area, the spatial association of major concentrations of gold deposits, porphyry intrusions, carbonate-rich rock zones, medium-scale anticline-syncline pairs (in contrast to major synclinoria), and major volumes of sedimentary rocks in two linear belts with at least one major angular unconformity (the "Temiskaming-Keewatin" unconformity) in each sedimentary belt, is interpreted as the result of a high concentration of faults and extensional strain, and localization of a particular type of magmatic, hydrothermal, and denudational-sedimentary activity in these two linear zones.

Specifically, the carbonate-rich zones are interpreted as being due to hydrothermal alteration localized mainly (but not entirely) along permeable fault zones. The faults provided the conduits for the emplacement of the porphyry bodies and the hydrothermal solutions which deposited the gold. The sedimentary rocks were deposited in half-grabens formed in the hanging wall blocks of major (listric?) normal faults. Angular unconformities resulted when major periods of extensional strain caused bedding in "older" (originally termed "Keewatin Series") rocks to be rotated before or during the deposition of the overlying "younger" (originally termed "Temiskaming Series") rock sequences.

The inclination to the fault planes of the axial planes of the "early" folds associated with them (e.g. the Porcupine Syncline, Ferguson *et al.* 1968, and Figure 1), and the left-lateral sense of drag indicated by these folds indicate a component of left-lateral strike slip movement on the two major faults in the area (Figure 1). However, the lack of significant offset of linear zones, defined in part by features in the rock sequences cut by the faults (Figure 1), combined with the abrupt change in stratigraphy and facing direction across the faults, and the presence of the associated sedimentary belts (linear basins = half grabens), suggest that the dominant slip direction on the faults was vertical, not horizontal.

Furthermore, the fact that the synclines of anticline-syncline pairs associated with faults (e.g. the Porcupine Syncline and the Larder Lake Syncline, Figure 1) occur in the hanging wall blocks, and the anticlines (e.g. the Shaw Dome and the Gauthier Anticline, Figure 1) occur in the footwall blocks of the faults, is consistent with an origin of the folds by drag on the fault planes. This assumes that the dip of the fault can be inferred from the regional sense of bedding rotation (i.e. that the regional facing direction in the vicinity of the faults is northward on the Porcupine-Destor Fault and southward on the Kirkland-Larder Lake Fault).

The folds, and thus the movement on the faults with which they are associated, at least in part, pre-date the "younger" sedimentary sequences since the unconformity in the Timmins area between the "younger" and "older" sedimentary sequence lies unfolded across the north and south limbs of the Porcupine Syncline in the "older" sequence (Ferguson *et al.* 1968; Pyke 1980).

Regarding the localization of major gold deposits and camps by structural features in the area, it is notable that major deposits occur where the faults (and associated sedimentary rock belts) trend northeast, and particularly near where northeast-trending segments bend into other orientations and/or are intersected by fault splays trending in other directions (Figure 1). It is perhaps sig-

nificant, in this regard, that a left-lateral component of strike slip on the two broadly east-trending major fault zones would result in dilation of northeast-trending segments (inset, Figure 1).

There is considerable evidence that most, and perhaps all of the gold deposits formed during and shortly following the period of porphyry intrusive-extrusive magmatic activity, which was associated with the tectonic event which caused the "younger" sedimentation. This evidence includes:

1. There is a marked spatial, and therefore probably also a genetic, association of porphyry intrusions and gold (see below).
2. The porphyries and gold deposits are commonly found in faults with which the early (pre-Temiskaming and Dome-Three Nations Lake Formations, Pyke 1980) folds are associated. They must, therefore, post-date the mafic volcanic rocks which are involved in these folds.
3. In the Kirkland Lake-Larder Lake area, trachytes which are petrologically similar to the intrusive porphyries are interbedded with the Temiskaming sedimentary rocks. Abundant locally derived porphyry clasts occur in the conglomeratic facies of both the Temiskaming Formation of the Kirkland Lake area, and the Dome Formation of the Timmins area.

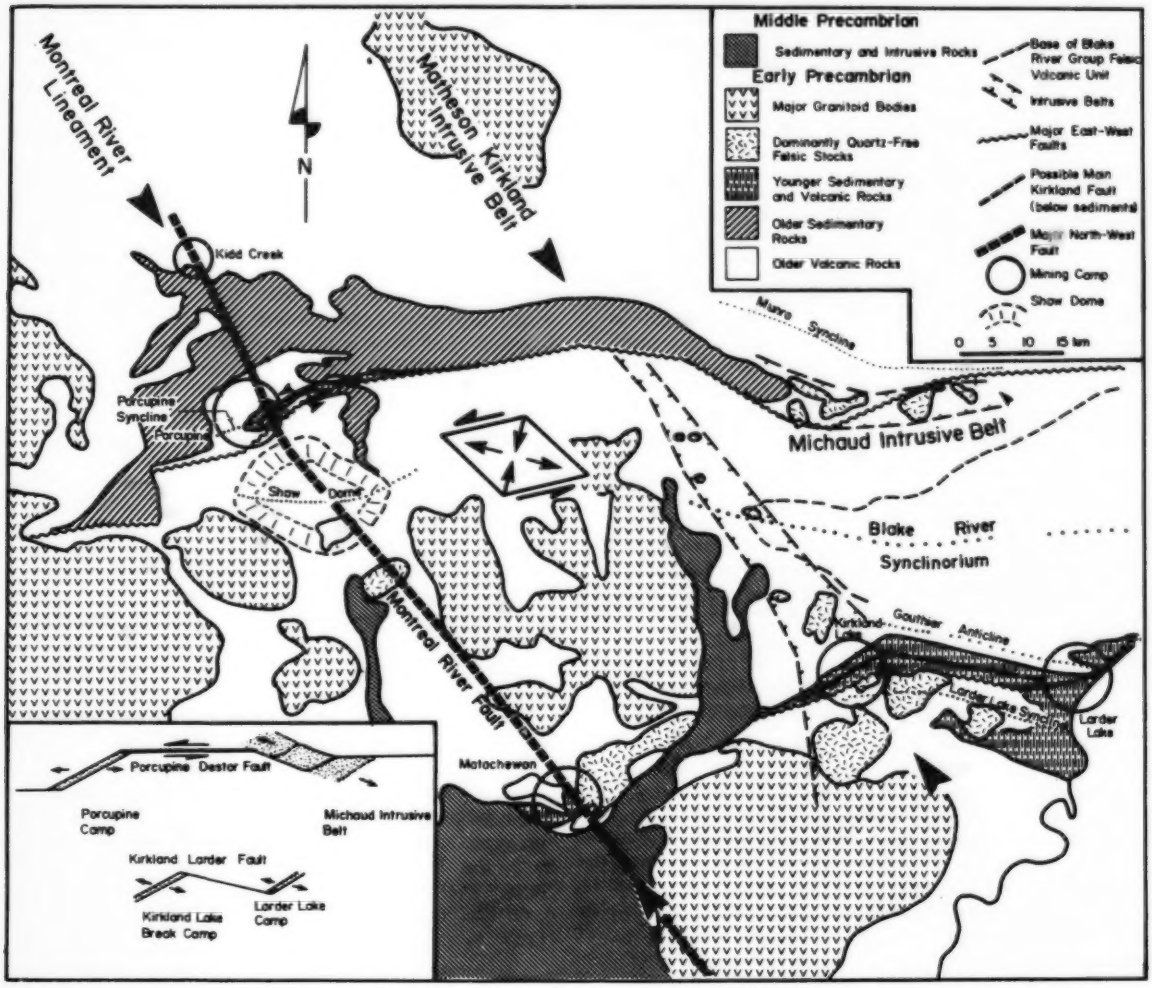

Figure 1—Generalized geological map of Timmins-Kirkland Lake area, showing relationship of major lithological and structural features to gold mining camps and major massive copper-zinc sulphide deposit (Kidd Creek copper-zinc Deposit; Porcupine Camp; Matachewan Camp; Kirkland Lake Camp; Larder Lake Camp). Inset map shows diagramatically how minor component of left-lateral strike slip movement on major easterly faults could lead to extension in northeast-trending segments (dotted pattern zones) of the faults, resulting in the localization of porphyry intrusions, carbonatization, and gold mineralization in these areas.

4. Large gold orebodies occur in the younger sedimentary rocks (Pamour Mine, Dome Mine) and in intrusions which cut these (e.g. within the Kirkland Lake Main Break).
5. Although the case for syn-mafic volcanic ore in the Dome Mine has been strongly argued (see review by Fyon *et al.* 1982), the following observations do not fit this interpretation:
   - interflow orebodies which occur directly along strike in the Paymaster Mine from the "ankerite veins" interpreted as chemical sediments in the Dome Mine cut across well-defined stratigraphic units in fold hinges (see Chart K, Section 7, Ferguson *et al.* 1968);
   - the base of the Dome-Three Nations Lake Formation must be an unconformity because it cuts across 12 500 m of stratigraphy in the underlying volcanic and sedimentary rocks. This unconformity must pre-date the Porcupine Syncline because it trends across the structure from the north to the south limb when traced westwards, and yet is not folded. But the base of the Dome Formation is the "Greenstone Nose" in the Dome Mine (i.e. the volcanic-sedimentary rock contact in the mine is an unconformity). Roberts (1981) has traced individual "ankerite veins" from an interflow position in the volcanic sequence into the conglomerate and breccias at the base of the Dome Formation, across this major angular unconformity. Therefore the "ankerite veins" must be true veins, and not chemical sedimentary rocks.
6. The suggestion that chemical sedimentary gold ore occurs in the area of the Buffalo Ankerite-Delnite Mines (Fyon *et al.* 1982) is suspect since the same zone of carbonatization which hosts the ore is transgressive to stratigraphy in the Dome Mine to the east, and the sequences on either side of the zone face in opposite directions (Ferguson *et al.* 1968).

Characteristics of Deposits

The following represent only a few of the many patterns defined by the data in the file.

Exploration History

All of the major camps and individual mines which eventually accounted for 86 percent of the gold ore produced to date in the area were discovered before 1915, in the 10 years following the first significant gold discoveries in the area. In this same period, only 15.4 percent of the total of 725 deposits (26.9 percent of the deposits for which discovery dates are known) had been discovered.

A second major cycle of exploration was initiated by the increase in gold price at the beginning of the depression, but produced far fewer significant discoveries. With the exception of Owl Creek, no production has yet resulted from the new discoveries which resulted from the massive sulphide exploration boom of the 1960s, and the subsequent new "gold rush" brought on by the increase in gold price in the early 1970s.

Thus, the gross value per discovery decreased exponentially from the time of the first discoveries. This exploration history is interpreted as reflecting the effectiveness of early prospecting efforts, and the ineffectiveness of modern exploration technology to test the potential of the very large tracts of covered ground in the area. This is confirmed by the tabulation of discovery method, which shows that 75 percent of the deposits were found by traditional prospecting methods, 14 percent by drilling or trenching of geological targets, and only 9 percent by drilling or trenching of a geophysical target. Only two deposits are documented as geochemical discoveries.

Economic Characteristics

The deposits have been ranked into seven classes on the basis of their economic merits. The five higher classes are divided by an order of magnitude difference in total ounces of contained gold or what were interpreted as equivalent values of "ounces per vertical metre", with the top class consisting of deposits with ≥1 000 000 ounces of contained gold.

Although most of the deposits with production and reserve data have production and reserves between 10 and 1000 ounces, 86.7 percent of the production and reserves have come from the 2.5 percent of the total deposit population with production and reserves of ≥1 000 000 ounces. Almost 75 percent of the deposits fall into the two lowest classes, which have been defined as deposits with "best intersections" of less than 1 m of 0.1 ounce per ton equivalent (intersection width by assay <0.1 ounce metres per ton) and deposits for which only grab sample grades are recorded.

The analysis of the relationship between geological and economic characteristics remains to be completed, as does the analysis of patterns in the distribution of deposits in relation to their economic rank.

Lithology

A very large quantity of information on the lithology of the associated rocks and their relationship to mineralization is recorded in the file, and only a very few of the significant patterns can be mentioned here.

Anomalously common in the vicinity of gold deposits are dikes and stocks which occur in 41.9 percent and 25.9 percent, respectively, of the deposits. Particularly common are intrusions of the felsic alkalic suite of rocks: 40 percent of deposits contain one or more of syenite, syenite porphyry, or felsic feldspar porphyry. An additional 14 percent of the deposits contain quartz-bearing porphyry intrusions.

A somewhat surprising lithological association is diabase dikes, which occur in 27 percent of the deposits, presumably because the dikes, which normally are post-ore, and ore are both controlled by the same structures.

Most of the other associated rocks are not much more common in the gold deposits than they appear to be in the area as a whole, although felsic volcanic rocks (38 percent of deposits) and clastic sedimentary rocks (34 percent of deposits) are somewhat more common than might be expected. A conspicuous exception is chemical sedimentary rocks, which occur in 11 percent of the deposits. Furthermore, when they occur in a deposit, chemical sedimentary rocks are much more likely to be the ore host than other lithologies. However, it should be emphasized that in almost 90 percent of the deposits, there is no evidence of the presence of chemical sedimentary rocks. Furthermore, it appears likely that, when the parameters "economic rank" and "lithology" are compared, deposits containing chemical sedimentary rocks are more likely to be poor, economically, than those with (for example) porphyry.

Mineralization

Most of the total of 809 gold mineralized zones in the file are described as tabular (80 percent of zones) or irregular (19 percent of zones). Data on relationship of gold zones to stratigraphy were recorded for 349 zones, and about half of these are concordant or nearly so, and half are clearly discordant. Thus, on the basis of the criterion of "unconformability", almost one quarter of the deposits in the area might be considered to be of chemical sedimentary origin. However, most of the evidence, in the author's opinion, indicates that there are no syngenetic, chemical sedimentary ores in the deposits included in this study.

The great majority of the mineralized zones consist dominantly of larger vein (45 percent of zones), smaller veinlet (35 percent), or disseminated (19 percent) mineralization. The most common "subordinate mineralization type" is disseminated (50 percent), followed by veinlet (40 percent) mineralization.

The "dominant alteration type", which is recorded for about half the zones, is most commonly carbonatization (53 percent) or silicification (21 percent); subordinate alteration in one quarter of the zones is pyritization (16 percent), carbonatization (15 percent), or chloritization (12 percent).

The dominant mineralogy of the mineralization is as might be expected: virtually all zones contain quartz, carbonate, and pyrite. There are, however, some minor minerals which show much more limited distribution, and some interesting relationships to the types of rocks which occur in the deposits.

Galena occurs in 14 percent of the deposits and, in 55 percent of these cases, one of the suites of felsic alkalic intrusive rocks is also present, whereas only 40 percent of the entire deposit population contains this rock suite. Molybdenite (9 percent of deposits) and tellurides (2.4 percent) show an even stronger association with the alkalic felsic intrusions; these rocks occur in 64 percent of molybdenite-bearing and 73 percent of telluride-bearing deposits. There is also a strong association of molybdenite with quartz porphyritic intrusions; 26 percent of molybdenite-bearing deposits contain these lithologies, whereas only 14 percent of the total deposit population contains them. Tellurides and galena are not, however, preferentially associated with quartz-porphyry intrusions. Tourmaline (5.3 percent of deposits) is strongly associated with quartz porphyry intrusions; 36 percent of deposits with tourmaline also contain these rocks. However, tourmaline is negatively related to the alkalic felsic intrusive suite, which only occurs in 21 percent of the tourmaline-bearing deposits, whereas 40 percent of the deposits in the population contain them. Scheelite, which is reported in only 1.5 percent of the deposit population, also is strongly associated with quartz porphyry intrusions. Arsenopyrite, another supposed common associate of gold, is reported in only 6.3 percent of the deposits. It is negatively correlated with the felsic intrusive suite, and positively correlated with ultramafic volcanic and/or intrusive rocks. Sphalerite, which occurs in 11 percent of deposits, shows no obvious positive or negative associations with any of the lithologies.

Conclusions

A great deal of further work is required to fully realize the useful information in the file, and to correlate the patterns shown by the deposit data with the regional geological patterns. Among the more interesting possibilities which it will be feasible to investigate is that of defining "anomalous areas of gold concentration" by plotting the spatial variations in the ratio of "deposits with certain features" to "total deposits". Obviously, the features chosen would be those which correlate with economic rank; defining such correlations (i.e. the criteria which separate the "winners" from the "losers"), will also be a major focus of future studies.

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No. 30 Placer Gold Potential of the Gowganda Formation along the Northern Margin of the Cobalt Embayment

D.G.F. Long[1] and C.A. Leslie[2]

Introduction

The finger-like outcrop pattern of lower Aphebian strata along the northern margin of the Cobalt Embayment (Figure 1) suggests the development of major paleovalley systems during Huronian times. Some of these systems contain more than 1 km of sedimentary rocks (Thomson 1943, 1957; Ambrose and Ferguson 1945; Mandziuk 1980) and may have exhibited considerable synsedimentary relief. The paleovalleys may have developed along existing north-trending zones of weakness, in the Early Precambrian (Archean) basement, during periods of valley-type glaciation (Lovell 1971) or by glacial re-excavation of pre-Gowganda paleovalleys. Card, McIlwaine, and Meyn (1973) suggested that deposition of the Gowganda Formation was at least in part controlled by the development of north-directed grabens, which may have been active during sedimentation. McIlwaine (1978) and Mandziuk (1980) also suggested tectonic control on sedimentation within the paleovalley systems.

Irrespective of their origin, all of these paleovalley systems transect gold-bearing strata of the Timmins-Kirkland Lake-Larder Lake mining camps, and consequently must have drained this area in middle Huronian times (Figure 1). As placer gold concentrations are present in fluvio-glacial outwash deposits of Pleistocene age, with similar provenance (Ferguson and Freeman 1978, p.186-190), it is reasonable to assume that placer concentrations could occur in Huronian outwash deposits. In order to test this hypothesis a detailed regional sedimentological investigation of the Gowganda Formation in the northern part of the Cobalt Embayment was initiated. Numerous samples were collected to determine if gold concentrations could be related to specific lithologies or depositional environments (Colvine 1981; Long 1981). A detailed study was made of the Kenogami Lake paleovalley (Figure 1, paleovalley B) in order to determine paleographic constraints on sedimentary styles.

Preliminary Results

Results of chemical analysis of the samples collected in the summer of 1982 are not yet available. Gold concentrations in two samples of mixtite (tillite) from the Larder Lake trough (Figure 1, paleovalley A) contain 10 parts per billion gold (Mandziuk 1980). Higher concentrations might be expected where traction currents have concentrated the heavy mineral fraction. Investigation of the stratigraphy and sedimentology of the Gowganda Formation suggests that much of the formation is of deep-water origin. Evidence of deposition in fluvial settings was not found, hence fluvial-placer concentrations cannot be expected. While a glacial influence is evident in many parts of the formation (extensive mixtites, graded laminites with outsized clasts and aggregate sediment pellets) other processes, including deposition from suspension (below wave base) and from sediment gravity flows (slumps, debris flows, grain flows, turbidity flows) are also important. Gold concentration may occur in the upper parts of turbidity flow units, or in well-sorted, laminated, fine-grained sandstones deposited in subaqueous mid-fan environments. Conglomeratic channel fills in this environment may be favourable targets.

No evidence was found to support a valley-glacier model for the evolution of the Gowganda paleovalleys. While most of the basal contacts exposed were sharp, with no apparent development of paleosoils (supporting a glacial origin) the absence of ice-marginal deposits, fan delta, and talus deposits (Wood 1980) along the margins of the paleovalleys suggests erosion and deposition below a continental ice sheet or ice shelf (Legun 1981).

Evidence of syntectonic activity was found in the Gowganda area (Figure 1, paleovalley G). At a location in the northern part of claim block RSC99 (McIlwaine 1978) sulphide cobbles and boulders were found in a subaqueous channel fill deposit in association with clasts of locally derived "greenstone". The channel fill conglomerate overlies a sequence of mixtites and laminites containing clasts of more exotic origin. The source of the sulphide boulders may have been within a few kilometres of this locality. Sulphide boulders were also found in the Kenogami Lake area in concentrations of less than 1 percent. Sandstone dikes, intruding mixtite, at a locality east of Huston Lake in MacMurphy Township, are also indicative of syndepositional tectonism.

Prospects for placer gold concentrations in the Gowganda Formation of the northern part of the Cobalt Embayment are poor, due to the absence of fluvial strata. However, knowledge of the distribution of gold in these strata may be of use in delineating gold concentrations in

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overlying strata of the Lorraine Formation (Colvine 1981) especially in areas where the contact between these formations is erosional.

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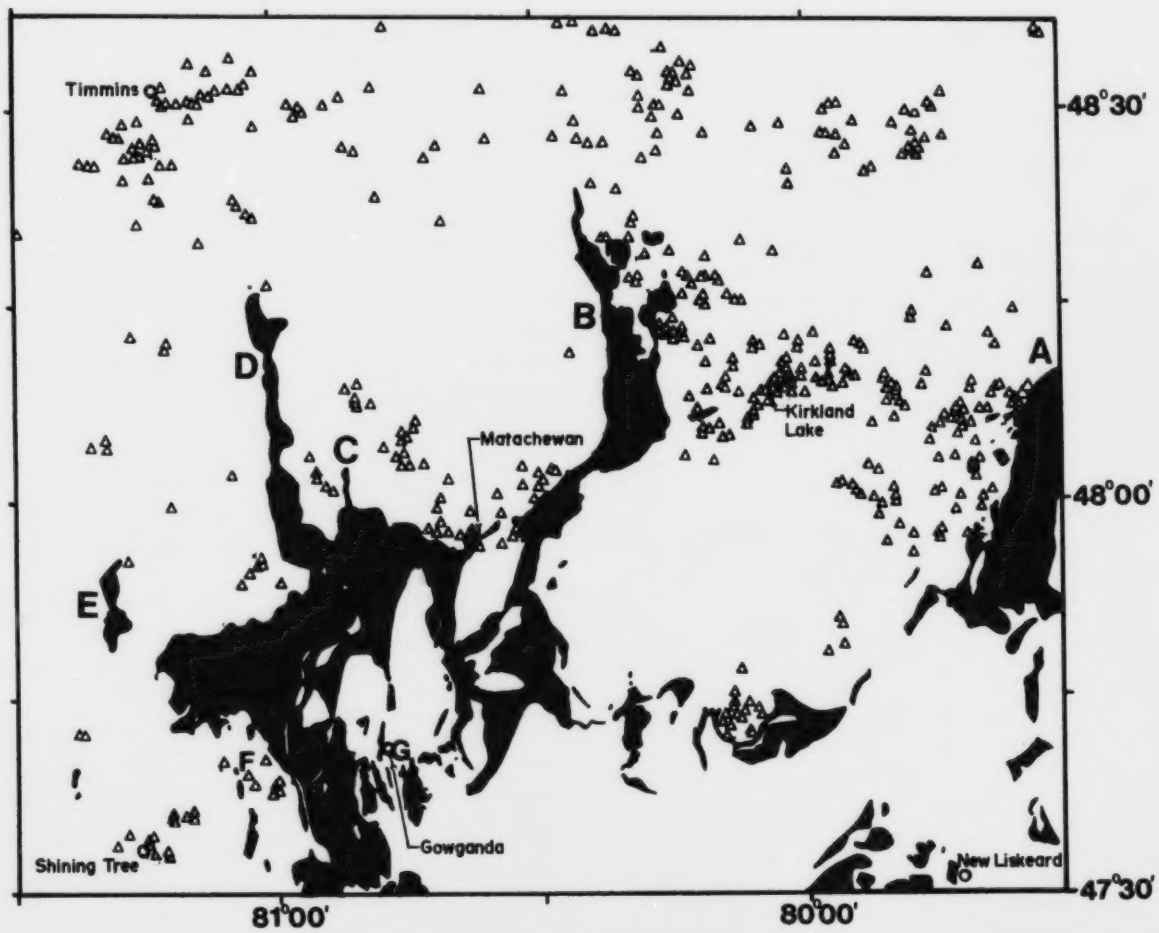

Figure 1—Distribution of the Gowganda Formation along the northern margin of the Cobalt Embayment (in black). Locations of gold occurrences (triangles) are from Pyke, Ayres, and Innes (1973). Paleovalleys are represented by the following letters: A – Larder Lake trough; B – Kenogami; C – Argyle; D – Rat Mountain; E – Loonwing Lake; F – MacMurchy; G – Gowganda.

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No.31 Geology of Lundy Township (Northern Half), District of Timiskaming

Leo Owsiacki[1]

Introduction

Lundy Township is bounded by Latitudes 47°29'N and 47°35'N and Longitudes 79°53'W and 80°01'W and is approximately 20 km west of the Town of New Liskeard in northern Ontario. Field mapping during the summer of 1982 in the northern half of the township concluded the second stage of a two-year project to determine the geology and mineral potential of the township. The geology of the southern half of the township is described in Owsiacki (1981).

Mineral Exploration

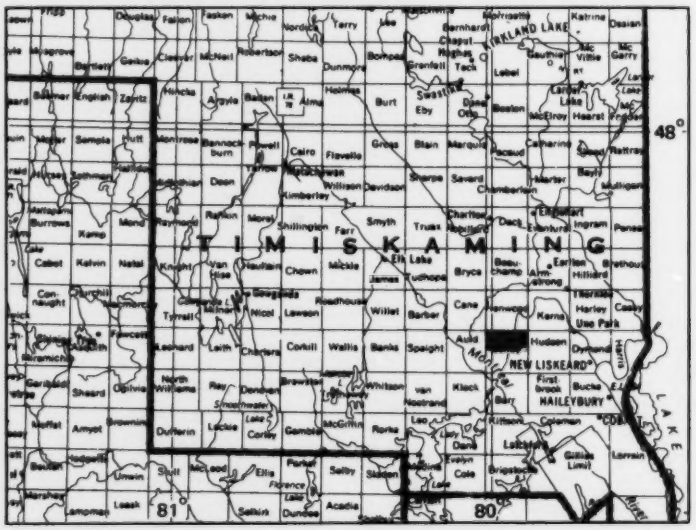
Limited claim staking took place in the northeastern part of the township between the years 1945 and 1970. Since then, little work has been performed on the few patented claims. There are no past or present producing mines in the township.

Assessment information has been submitted for only one claim, in the southeast corner of concession V, lot 4, held in 1953 by the Alex J. Godzik Group and worked by Harold Walton in 1972. Ten shallow pits blasted in a 125 by 175 m area exposed chalcopyrite mineralization. Assays of up to 2.52 percent copper over 1.5 m widths were described (Resident Geologist's Files, Ontario Ministry of Natural Resources, Cobalt).

Reports in the assessment files describe copper and cobalt mineralization from numerous pits in the township. The locations of these pits are uncertain.

During the 1982 field season, several prospectors undertook reconnaissance trips to the southern half of Lundy Township on the basis of information in Owsiacki (1981).

[1]Resident Geologist, Ontario Ministry of Natural Resources, Cobalt.



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

General Geology

The eastern part of the township is readily accessible from numerous trails leading from concession roads terminating at the township boundary. The western part is accessible by fixed-wing aircraft to Lundy Lake.

Lithologies in the northern half of the township include sedimentary rocks of the Firstbrook Member (Gowganda Formation) and the Lorrain Formation of the upper Huronian Supergroup, and sills and dikes of Nipissing Diabase and younger mafic intrusive rocks (Figure 1, Table 1). Rocks of the Coleman Member (lower Gowganda Formation) are exposed only in the southern half of the township (Owsiacki 1981).

Firstbrook Member sediments, which lie stratigraphically below those of the Lorrain Formation, are exposed in the northeastern part of the township. A distinct transition occurs over a 50 m interval at the contact of the Firstbrook Member with the overlying Lorrain Formation. This zone consists of massive, maroon siltstones and less than 1 m thick interbeds of thinly laminated maroon/green argillite. Ripple marks were observed where the siltstones are relatively massive.

The transition zone passes downward into a very thick sequence of thinly laminated, maroon/green argillite. Locally, the laminae become quartzitic and pinkish in colour and exhibit an almost gneissic texture. Laminae are consistently parallel and usually less than a few centimetres thick. Other than minor microfaulting and variable thinning and thickening, the laminae exhibit few sedimentary structures. In the immediate vicinity of Nipissing Diabase intrusions, the argillite, in some instances, loses its reddish colour, which may be indicative of restricted thermal metamorphism.

The northwestern part of the township is underlain by a thick sequence of clastic sediments of the lower Lorrain Formation. Two principal lithologies are recognizable. The lowermost unit consists of a fine-grained, grey, basal feldspathic sandstone characterized by red clots of feldspar concentrated along bedding planes. This sandstone grades upward over a short interval into a relatively clean, fine- and coarse-grained quartzitic unit that occurs in thin, discontinuous lensoid and interfingering beds which commonly concentrate into thicker bands. Rock fragments are rare in the quartzite and are normally less than 2 cm in size. Greenish beds of a more massive, sugary textured quartzite sometimes occur within this unit. Weathered outcrops are pink to white; jointing is poorly developed and irregular.

There is an upward transition, over a 20 m interval, from the quartzitic sandstone to a thick bedded, relatively uniform, coarse-grained arkose. The base of the arkose is characterized by channel-type fillings of fine-grained, thinly bedded, shaley sandstone. These beds are commonly less than 25 cm thick and are warped by the thick beds of massive arkose that overlie them. This imparts a pillow-like appearance to the rocks, similar to the structure described in basal Lorrain Formation wackes in Firstbrook Township (Johns 1980).

The arkoses resemble, in some ways, the underlying quartzites. They consist of thin beds of interlensed medium- and coarse-grained sand. Major differences include a much higher feldspar content and larger grains (up to approximately 1 cm). Rock fragments to 3 cm in diameter comprise 1 percent of the rock. The lithology is also characterized by the presence of sericite and a pervasive hematitic stain. Discordant yellow-green bands and lenses bound narrow fractures and are commonly confined to beds. A purple colour, due to irregular clots of hematitic staining, is imparted to the rock as a whole. The two types of staining, probably due to weathering, occasionally occur as halos around rock fragments and sand grains.

Two episodes of Nipissing Diabase intrusion are inferred. The earlier diabase was intruded as an extensive sill, primarily into Firstbrook Member sediments. The sill dips moderately to the west and forms the east limb of a diabase basin, the west limb of which crops out in Auld Township. It is characterized by a consistent vertical zoning. The upper half exhibits a coarse-grained, varied texture and is identified by the presence of irregular pockets of pegmatitic material in a finer grained matrix of similar composition. A gradual downward change occurs to a zone of massive, medium-grained pyroxene (hypersthene?) diabase, which in outcrop characteristically exhibits a clotty appearance with brown, weathered, euhedral, pyroxene phenocrysts in a slightly finer grained matrix. A thin zone of fine-grained diabase occurs at the base of the sill.

A rhythmically layered phase of this sill is exposed in the northeastern corner of the township. Alternating bands of fine- and coarse-grained crystal cumulates range in thickness from 1 mm to 10 cm. The banded phase is in sharp contact with a very coarse grained, massive gabbro which exhibits radially concentrated feldspar crystals. Pods of granophyre have formed along the contact and flow structures are evident within the layers of the banded phase. Further studies will be undertaken in this area to interpret the possible mechanisms of intrusion of the sill.

A second diabase body crops out in the northeastern half of the township. Contacts of this diabase with the surrounding lithologies appear to be near vertical and it is dike-like in that it seems to crosscut the zones defined within the diabase sill. The central part consists of a coarse-grained, varied textured diabase similar to that in the upper parts of the sill as described previously, but the massive pyroxene zone is absent and a dense black quartz diabase which envelops the varied texture zone is present. This relationship suggests intrusion of this diabase as a dike which cooled from both margins towards its centre.

The intrusive relationship between these two Nipissing Diabase bodies in Lundy Township is inferred. Thom-

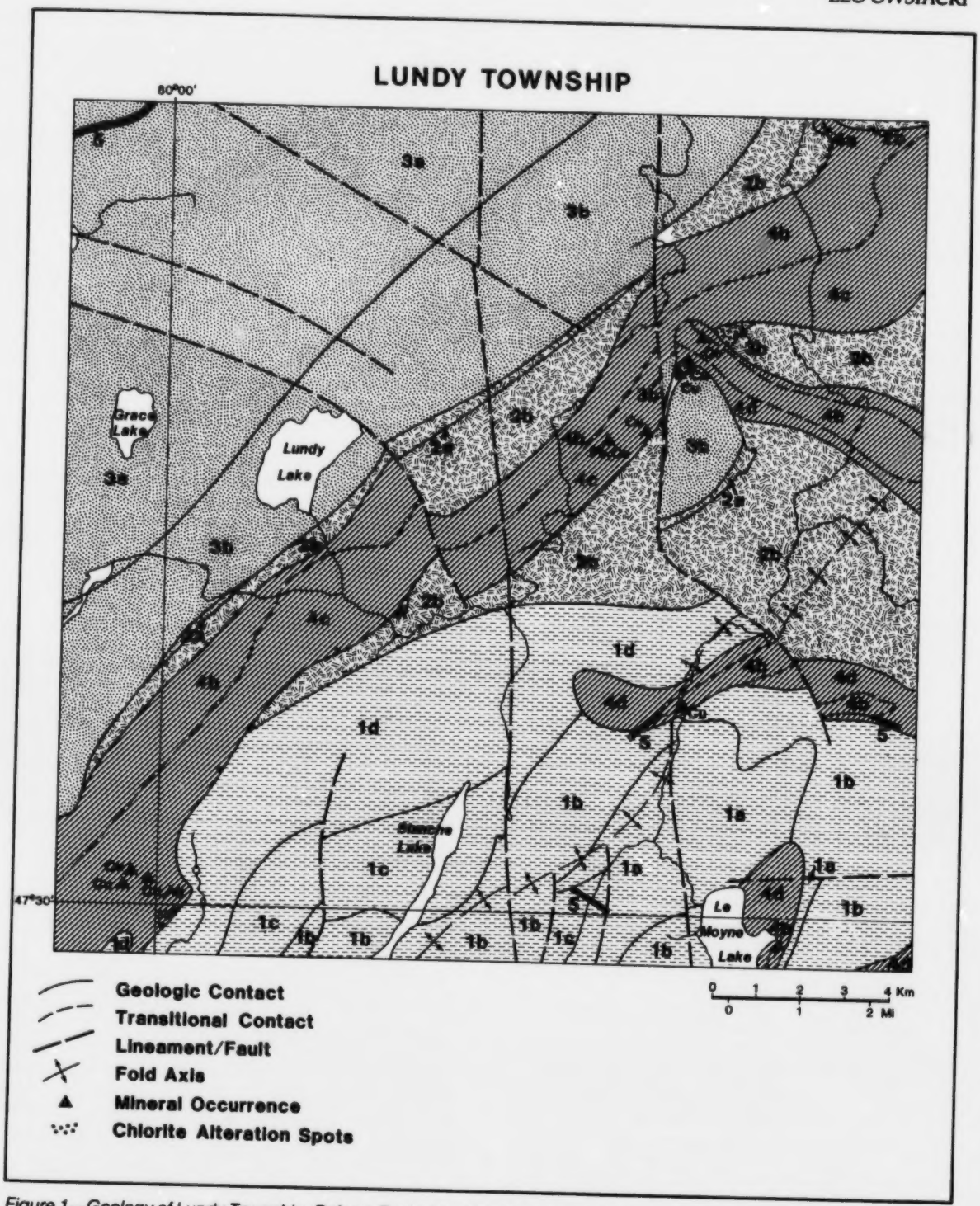


Figure 1—Geology of Lundy Township. Refer to Table 1 for identification and description of the map units.

TABLE 1 | **TABLE OF LITHOLOGIC UNITS**

UNIT	
	PROTEROZOIC
5	Olivine diabase, diabase
	INTRUSIVE CONTACT
	Nipissing Diabase
4a	Rhythmically layered and granophyric
4b	Varied textured (irregular, coarse-grained pockets in a finer grained matrix of similar composition)
4c	Pyroxene diabase (medium grained, massive rock characterized by brown, weathered pyroxenes)
4d	Quartz diabase? (dense, black (augite?), medium grained, massive)
	INTRUSIVE CONTACT
	HURONIAN SUPERGROUP
	COBALT GROUP
	Lorrain Formation
3a	Arkose (coarse grained, purple; thickly bedded; characterized by hematitic and sericitic alteration)
3b	Quartzite (medium grained; weathers pink and white; mixture of fine and coarse grain sands in thicker beds) The base of this unit grades into fine-grained, grey sandstone characterized by red, felsic clots aligned along bedding planes.
	Gowganda Formation
	Firstbrook Member
2a	Siltstone (maroon, massive, local interbeds of thinly laminated argillite)
2b	Laminated Argillite (alternating maroon, pink and green laminae; laminae less than 5 cm thick; quartz and silt-rich zones common)
	Coleman Member
1d	Grey Argillite (very fine grained laminae less than 0.5 mm thick; slaty cleavage; silty at base and top of unit)
1c	Siltstone (fine grained; grey/maroon; characterized by thin phyllitic laminae and dropstones at base)
1b	Pebbly Wacke/Conglomerate (pebbles and cobbles comprise 2 to 35% of a siliceous matrix of rock flour)
1a	Green Argillite (thinly laminated; extensive small scale slump folding)

son (1968) has also identified two diabase sills in Henwood Township to the north.

Narrow olivine diabase dikes also occur in the township. These commonly have fine-grained margins and coarser interiors and crosscut both Huronian sediments and Nipissing Diabase intrusions.

Structural Geology

Lineaments are the dominant structural feature in the map-area and are clearly outlined on aerial photographs. Two prominent sets are apparent. In the northwestern part of the township, northwest-trending lineaments are accompanied by parallel sets of closely spaced joints which seem to intensify towards the lineaments. Quartz veining occurs locally within the sediments and usually within 50 m of the lineaments. The veins are quite flat and tend to parallel the bedding in the sediments. No mineralization was observed in the veins. Although movement can be inferred in some, most of the lineaments appear to be major joints.

A second set of lineaments and accompanying parallel joints trend north and dominate the north-central part of the township. They are similar to the northwest-trending structures. The easternmost lineament may represent a major fault and have some control on the occurrence of the outlier of Lorrain Formation quartzites in this area.

A third, west-trending lineament set is present but is poorly developed relative to the sets previously described. In one instance, quartz veins and slickensides were found along the plane of breakage.

The sedimentary rocks of the Firstbrook Member and the Lorrain Formation dip gently from 4 to 18°W in an un-

dulatory fashion and define the west flank of a major anticline exposed in the southeastern part of the township (Owsiacki 1981).

Laminated argillites of the Firstbrook Member in contact with the Nipissing Diabase in the northeast corner of the township may have undergone local deformation. Dips of the laminae increase from 24 to 68°N as the contact is approached. No internal disruption of the laminae is evident and the steepening may be indicative of forceful intrusion after consolidation of the sediments.

Economic Geology

A number of different Pleistocene deposits are exposed throughout the township. Clay beds are present but are not extensive and may represent marginal extensions of Lake Barlow-Ojibway. The dominant feature in the north, central, and eastern parts of the township is a glacial outwash plain composed primarily of sand and thin gravel beds (Roed 1980). Ground moraines and associated tills predominate in the northwest and minor peat bogs border some of the shallow lakes. To date, no gravel has been extracted from the township and the potential for discovery of extensive gravel deposits is minimal.

Metallic mineralization was noted in several locations (Figure 1). In addition, numerous old, shallow, previously unrecorded pits were located. Galena and chalcopyrite were found as crystals within clots in asbestos-filled fractures in one outcrop of the central diabase sill. The fractures are numerous, variable in trend and dip and probably reflect a fault zone. Minor amounts of copper occur to the northeast of this showing in a narrow, white, calcite vein within and near the base of the diabase sill. The vein parallels local vertical joints which trend in a westerly direction.

An erythrite seam containing trace amounts of chalcopyrite is exposed for 5 m within the medium- to coarse-grained phase of the Nipissing Diabase dike near its contact with the main diabase sill. Sediments bordering the southwestern contact of this intrusion are enriched in chalcopyrite and malachite and have been trenched in numerous locations.

The copper mineralization occurs within dike-like offshoots of the main intrusion but is concentrated in the sediments near contacts with the diabase. The chalcopyrite is massive and is irregularly distributed within red (baked?) quartzitic sediments. Concentration is intimately associated with intrusion of the diabase body.

Trace element data for lithologies from the southern half of the township indicate that background values for most are much higher than those described by Boyle (1969) for similar rocks in the Cobalt silver camp. Unit 1d (Figure 1), an extensive grey argillite of the Coleman Member of the Gowganda Formation, is enriched in Zn, Sb, As, Ni, Pb, Co and Cr relative to other Huronian lithologies. High values for these elements include:

Zn	395	ppm
Pb	131	ppm
Co	48	ppm
Ni	103	ppm
As	50	ppm
Cr	211	ppm
Sb	3.8	ppm

Many of these elements comprise the bulk of accessory metallic vein mineralization in silver veins at Cobalt, Elk Lake, and Gowganda.

Analyses show that quartz veins in Huronian sediments and diabase are very slightly enriched in gold. The Lorrain Formation arkose and quartzites are depleted in gold and average less than 2 parts per billion. Laminated argillites of the Firstbrook Member, on the other hand, average greater than 5 parts per billion gold as background and one distinct anomaly of 180 parts per billion gold was recorded within the unit in the southwestern part of the township.

Silver occurs in concentrations of less than 2 parts per million in all lithologies. One exception is an anomalous value of 8 parts per million obtained from vein-free diabase from the east-central Nipissing Diabase dike.

Cobalt and arsenic are anomalously enriched in several areas within the diabase.

Interpretation of these data is still preliminary and further analyses are presently being obtained for samples from the northern half of the township.

Chlorite alteration spotting is pervasive in siliceous sediments bounding the Nipissing Diabase intrusion to the north (Figure 1). The spotting is comparable in intensity, distribution, and form to that observed in the heart of the Cobalt silver camp. The spots comprise approximately 10 percent of the rock at the localities where they have been observed (Figure 1) and vary in concentration between beds. They range in size from 1 mm to 2 cm and typically comprise a dark chloritic core encircled by a narrow, pink felsic rim. Similar spotting occurs in a few isolated zones in the southern half of the township within Firstbrook Member argillites.

A ground radiometric survey, utilizing a McPhar TV-1 spectrometer, revealed no distinct anomalies. The highest values were obtained from granophyric phases of the Nipissing Diabase and laminated argillites of the Firstbrook Member. High total counts were probably a reflection of a higher potassium content in the host rock.

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No. 32 Petrology, Stable Isotopes, and Fluid Inclusions of the Ag-Co-Ni Arsenide Vein Deposits near Cobalt and Gowganda, Ontario

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Introduction

Since the discovery in 1903 of the Cobalt mining camp, its silver vein deposits have been the subject of numerous reports and studies. Despite this, however, fundamental problems concerning their genesis remain unsolved. For example, no reliable data exists with respect to (a) source of fluids, (b) source of metals, (c) timing of mineralization with respect to such prominent features as the Nipissing Diabase, (d) the relationship of various alteration features (e.g. chlorite spotting) to mineralization, and (e) the distribution of Ag-Co-Ni arsenide vein deposits with respect to the Cobalt Embayment.

A high quality data base has been well established in the Cobalt area in the form of Ontario Department of Mines 1 inch to 400 feet scale maps, and numerous reports produced by Thomson (1957 to 1964). This data base continues to evolve as reflected by recent studies in the area by Petruk (1971), Jambor (1971), Patterson (1979), Appleyard (1980), Owsiacki (1981), and Legun (1981). The maintenance of a high quality data base combined with recent technological advances in specialized geochemical techniques permits a controlled, field based, fluid inclusion-stable isotope study of the area to be made.

Objectives

The purpose of this project, which was initiated during

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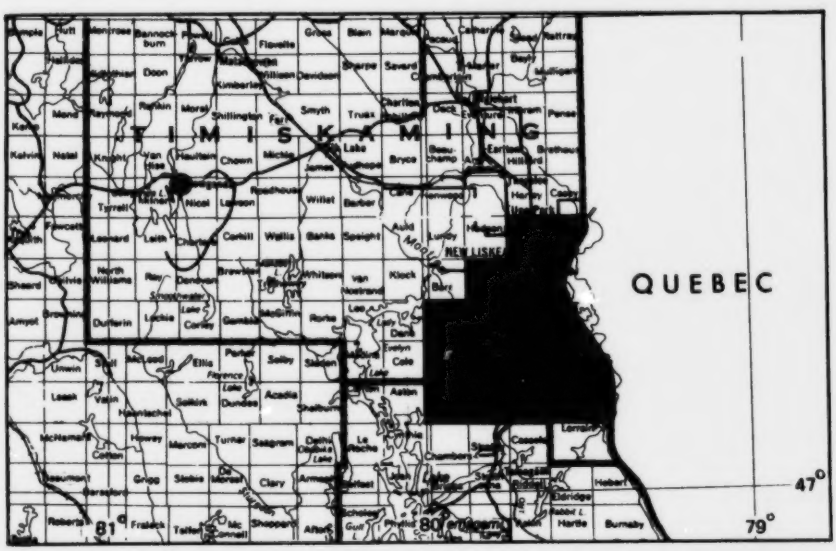

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

1982, is to characterize the probable source, transport medium and depositional environment of the Ag-Co-Ni arsenide vein deposits near Cobalt and Gowganda. It is approached on the basis of detailed mapping, sampling and petrographic examination of selected areas in these camps.

Samples of vein and altered host-rock material will be analyzed for whole rock and mineral oxygen isotopes. Fluid inclusion work on the vein material will concentrate on visual measurements of temperature, pressure, salinity, and composition. If warranted, the stable isotope investigation will be expanded in the second year to include hydrogen and carbon isotope measurements, and the fluid inclusion study to include dating, chemical analysis and possibly, stable isotope measurements.

Progress to Date

This summer, sampling was carried out at the Silverfields, Temiskaming, Pan Silver, Silver Century, and Langis Mines in the Cobalt camp, the Castle Mine near Gowganda, and selected parts of Nipissing Hill near the Town of Cobalt. Detailed follow-up mapping will be conducted at the underground sites during the coming fall and winter seasons. In all areas, samples were collected representing mineralized and non-mineralized veins, altered wall-rock adjacent to veins and various types of alteration features observed in the surrounding host rocks, possibly related to the mineralizing system. While numerous vein systems were studied and sampled, particular attention was given to major vein systems which are spatially extensive and represent significant producers of ore. These are (A) the No. 1 vein in the Pan Silver Mine which follows a major fault structure, transecting both interflow sediments in the Early Precambrian (Archean) basement and overlying Coleman sediments; (B) the No. 41 vein in the Temiskaming Mine, hosted by Early Precambrian (Archean) mafic volcanics and located beneath the Nipissing Diabase sill; and (C) the No. 01 vein in the Castle Mine, exposed over a vertical depth of more than 200 m and contained almost entirely within the Nipissing Diabase sill.

Vein Systems

Field observations concerning these vein systems and their host rocks are summarized as follows:

1. The majority of veins occur in association with shear zones, fault gouge, and breccia. As such, their generation appears to be fault and shear related as opposed to simple dilation. Multiple generation of quartz and calcite in these veins, some of which show evidence of cataclasis, gives evidence of a complex history of fault motion and vein formation.
2. Most veins show evidence of at least two generations of calcite, commonly consisting of a coarse-grained, vuggy, translucent variety along with a white, opaque, fine-grained type. The translucent variety often appears to be the earlier generation, and in some mines, is used as an indicator of good ore. The Pan Silver Mine is distinct from all the other mines visited, in that calcite contained in all the ore veins is of a pale pink colour. Close inspection of vein material suggests that the colouration may be due to a late stage alteration effect superimposed on an original, grey, translucent variety of calcite.
3. Silver ore occurs primarily within steeply dipping veins. In most of the mines there is a persistent, well developed system of flat to gently dipping veins containing calcite, but rarely, if ever, containing silver ore. These are characterized by the presence of epidote, potassium feldspar, and variable quantities of axinite (hydrous boro-silicate), chalcopyrite, and sphalerite. The flat veins are often fault related and in some instances, show cross-cutting relationships with the more steeply dipping ore veins.
4. While ore shoots are often controlled by particular lithological/structural environments, the veins themselves are vertically extensive and not confined to individual rock units. For example, at the Silverfields Mine, ore is confined primarily to where veins transect Coleman sediments, however, the vein systems themselves extend into the underlying Early Precambrian (Archean) basement rocks (to unknown depth) and into the overlying Nipissing Diabase sill where they are exposed at the present erosional surface. At the Castle Mine, Gowganda, vein systems extend completely through the Nipissing Diabase sill into the surrounding Early Precambrian (Archean) volcanic rocks. The relationship between these extensive mineralized fracture systems and the history of the Nipissing Diabase sills is not immediately obvious.
5. Silver-bearing carbonate veins cross-cut and/or follow pink, quartz-feldspar rich, fine- to coarse-grained dikes which intrude all rock types in the area including the Nipissing Diabase. These dikes, which are often referred to as granophyre and aplite, are considered by mine geologists of the area to be late stage differentiates of the Nipissing Diabase.
6. Petruk (1971) made the observation that in general, silver ore in the Cobalt camp occurs within about 500 to 700 feet of the Nipissing Diabase contact, a statement which has obvious genetic implications. Much of the available data concerning distribution of known 'ore' in the camp is historical and thus complicated by such parameters as mining methods and acceptable ore grades, that have changed drastically through time. For example, original mining often involved high-grading at thousands of ounces per ton, whereas at present, cut-off grades are in the range of 6 to 14 ounces per ton (5 feet mining width). Our observations suggest that the actual distribution of 'anomalous silver' in the area is extensive and complex. A direct, genetic relationship with the Nipissing Diabase intrusion based on spatial relationships has yet to be convincingly demonstrated.

Alteration

1. Chlorite spotting is an alteration type characteristic of the Cobalt camp. It is observed primarily in Huronian sediments adjacent to the Nipissing Diabase intrusion and has thus been attributed as a contact metamorphic effect. Since the Cobalt camp appears to be anomalous in both silver mineralization and the development of chlorite spotting relative to the surrounding regions, there has been a temptation to cite the latter as an indicator of ore. However, in a regional sense, the distribution of chlorite spotting with respect to Nipissing Diabase and its relationship to silver mineralization is not simple. For example, recent mapping by one of the authors (Owsiacki) in Lundy Township, located 30 km northwest of Cobalt, has revealed areas of Huronian sediment in contact with the Nipissing Diabase which are completely devoid of chlorite spotting, and other areas which are intensely spotted but completely devoid of any indication of silver mineralization.
2. Although chlorite spotting has been described in the Early Precambrian (Archean) mafic volcanics (Thomson 1961; Jambor 1971), in this environment it is much less common and less well defined than that observed in the Huronian sediments. Spotting tends to occur in a number of different forms and genetic relationships to the Nipissing Diabase intrusion are often uncertain. A rather unusual and spectacular example of "chlorite spotting" is observed in Early Precambrian (Archean) basalts underlying the Nipissing 401 Property, located on Nipissing Hill. These spots exhibit good crystal outlines of the orthorhombic system. As such they could represent chlorite retrograding of previously formed porphyroblasts.
3. Laminated siltstones occur as an important constituent of Early Precambrian interflow sediments. However, while they are grossly similar in lithology to their Huronian counterparts, in the areas we observed, they do not develop chlorite spotting, even when in close proximity to the Nipissing Diabase intrusion.
4. Wall-rock alteration associated with mineralized carbonate veins is distinctly variable from one area to another. For example, in the Silver Century Mine, veins hosted by Early Precambrian (Archean) basalts exhibit well developed, pink to red coloured alteration halos which we interpret as oxidation and/or K-metasomatism. In contrast, veins in a similar setting at the Temiskaming Mine, exhibit little or no obvious alteration, other than an occasional weak bleaching effect. At the Pan Silver Mine, fault-related veins hosted by Early Precambrian (Archean) interflow sediments and Coleman conglomerates are characterized by well developed chloritization of the wall rocks. Veins hosted by Nipissing Diabase observed at the Castle, Temiskaming, and Silver Century Mines exhibit alternating light and dark coloured bands in the wall-rock; presumably, carbonate and chlorite-rich material, respectively. The parameters affecting wall-rock alteration are undoubtedly numerous and their interplay complex; however, from the above, it seems that host-rock lithology and possibly vein type (i.e. shear versus simple dilation) may be significant factors here.

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No. 33 Gold and Base-Metal Vein Deposits in Eastern Ontario: Structural Inferences and the Significance of Vein Mineralogy

Janet S. Springer[1]

Introduction

Five localities with gold-bearing quartz veins were examined in 1982 for evidence of their structural association. Three are shown on the Kaladar map sheet (Wolff 1978): the T.C. Michie and Stone Occurrences, and the Addington (Golden Fleece) Mine. The adjacent sheets of the Clarendon Lake area (Moore and Morton 1980), and the Ardoch Lake area (Pauk and Mannard 1982) give the regional context. The other 2 localities, the Cordova and Ledyard Mines, and the Addington Mine, have been discussed by Carter and Colvine (1979) and Carter (1980).

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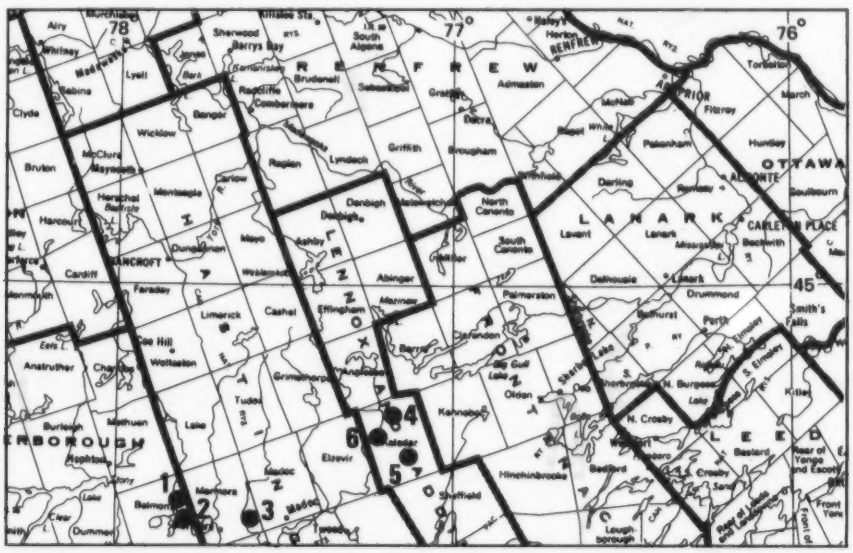
Furthermore, Thomas and Cherry (1981) examined the Cordova Gabbro for relationships between the body and its gold-bearing veins, and a brief discussion of the gabbro appears in the marginal notes to the Belmont Township map (Bartlett *et al.* 1982).

Evidence is presented herein for zonation of gold-bearing quartz veins in the Madoc district, which has consequences for the economic viability of these veins because the deeper ores are more refractory. It also influences the secondary concentration of gold and the outlook for successful reworking of tailings. Finally, segregations of pyrite in the Deloro granite are described, with a discussion of their possible economic significance.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

LEGEND

1 Cordova Mine
2 Ledyard Mine
3 Sovereign Mine
4 Addington Mine
5 T. C. Michie Occurrence
6 Stone Occurrence

Occurrences on the Kaladar Sheet

Since 1976, workers in this area have repeated Moore's (1976) hypothesis that gold and base-metal accumulations at the pre-Flinton Unconformity reflect either volcanogenic deposition in carbonate rocks associated with pyroclastic rocks, or secondary enrichment by metamorphic remobilization at the base of the Flinton, where it overlies volcanic rocks. On the Kaladar sheet, the unconformity is certainly the site of the 4 gold occurrences shown, but on the adjacent Clarendon Lake and Ardoch sheets, the relationship is less evident.

T.C. Michie Occurrence

At this occurrence, the northward approach to the Flinton Group is marked by rising ground. A 20 m high scarp facing southeast is the edge of a small fault block whose boundary trends N30°E and dips steeply southeast. The foliation parallels this strike, but dips gently 20° to 30° southeast. Quartz veins 2 to 10 cm wide cut the Flinton rocks; they are elongate lenses 10 to 15 cm long, and are clearly controlled in both strike and dip orientation by structural directions, such as axial planes and long limbs of minor folds. At the vein centres the quartz is clear and glassy, but at the margins it shows a porous texture with a mineral lineation. No sulphide mineralization is present, either in the quartz veins or in the host rocks.

Stone Occurrence

Here the boundary between older amphibolites to the west, and strongly layered quartzites with some biotite-quartz schists which mark the Flinton Group, trends N15°E and dips 75° to 80°E. The amphibolites are rusty and iron-stained with some sulphide remnants; quartz veins in the amphibolites are also iron-stained, but exposure does not allow their orientation to be measured. In the quartz-rich Flinton rocks numerous quartz lenses 0.5 to 5 cm wide and 5 to 10 cm long follow the strongly developed compositional banding, or locally cut it at low angles. No sulphide mineralization was seen within the Flinton rocks, or in the quartz veins, although visible gold in quartz is mentioned in earlier reports (Harding 1944).

Addington (Golden Fleece) Property

This property has recently been summarized by Carter (in preparation), to be published as an Ontario Geological Survey Geoscience Study, and is mentioned in earlier work (Carter and Colvine 1979; Carter 1980). The most complete previous report is by Bell (1949), who mapped the property at a scale of 1 inch to 200 feet and the ore zone at 1 inch to 100 feet. He concluded that the 4 main ore shoots are contained within a shear zone striking N10°E and dipping 65E°, which marks the boundary between metavolcanics to the west, and the quartzites and conglomerates of the younger Flinton Group (Figure 1). The contact is a structural one; the fault shows a normal sense of movement with the downthrown block lying to the east. The ore is largely confined to a zone of hornblende-biotite schist developed from the amphibolitic host rocks along the fault. Older records indicate a leaner ore zone west of the main shear in quartzites, but Bell (1949, p.9) concluded that this is an infolded, anticlinal window of the hornblende-biotite schist. Pyrite is reported as the principal metallic mineral, with lesser amounts of arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, and galena. Specimens examined in 1938 showed free gold in the gangue, in fractures in the arsenopyrite, and in association with magnetite. Metallurgical tests in 1939 (Bell 1949) recovered 95 to 99 percent of the gold by cyanidation after 60 percent of the ore was ground to −200 mesh.

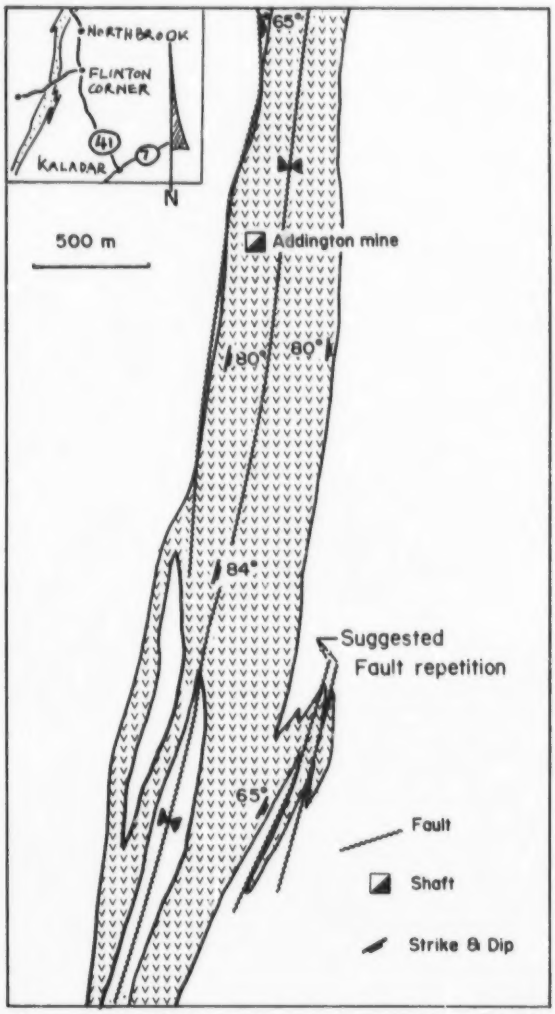


Figure 1—Faulted margins to a Flinton Group Syncline (after Wolff 1978, Map P.1563).

Material examined on the ore dump in 1982 contained veins of clear, glassy quartz with some ankerite in the amphibole-biotite schists. The sulphide minerals are strongly segregated at the vein margins, appearing to replace the amphibolitic material. There is little sulphidic material in the gangue, and where the whole thickness of a vein can be seen, the relationship to the banding suggests that these are replacement rather than dilation veins.

The Flinton Unconformity

The asymmetrical distribution of units within the Flinton synclines, apparent on the Kaladar, Clarendon Lake, and Ardoch map sheets, combined with evidence from the detailed mapping by Bell (1949) at the Addington Mine and reports of structural excision on the northern limb of the Fernleigh Syncline near Ompah (L. Pauk, Geologist, Ontario Geological Survey, Toronto, personal communication, 1982), suggest that strike faults between the competent Flinton metasediments and the older rocks are frequent in this area. The Flinton rocks are commonly preserved in narrow, sharply crested synclines with steeply dipping limbs, evident from the map sheets. Outcrop pattern, such as that seen on Map P.1563 (Wolff 1978) south of the road from Flinton Corner to Flinton, suggests that faulting has modified the main stratigraphic contacts and deepened the structural position of the synclines across the faults (Figure 1). It is therefore probable that these have provided structural sites which influenced the location of gold-bearing veins. The association with the Flinton unconformity may therefore be a structural artifact, rather than a zone of chemical accumulation. However, field evidence accumulated by the author, and earlier work, indicates that although the quartz veins are an easily visible field marker, the majority of sulphide (and therefore gold) mineralization, which lies close to the outer margins of the veins, is hosted by amphibolitic rocks or mafic derivatives of them. These relationships suggest that in some of the unconformable auriferous veins the host rock influences the vein mineralogy.

Structural Position of Gold Veins in the Cordova Gabbro: Cordova Mine and Ledyard Mine

The Cordova Mine has been summarized by Carter (in preparation) and both deposits are mentioned by him in earlier publications (Carter 1980; Carter and Colvine 1979). More specific work is reported by Thomas and Cherry (1981) and Bartlett *et al.* (1982). An M.Sc. thesis by Thomas is in progress at Ottawa University, Ottawa, Ontario.

Blue (1894) and Miller (1902) described both the Cordova and the Ledyard gold deposit, which lies at Universal Transverse Mercator coordinates 493450N, 279225E. Reports prepared for The Consolidated Mining and Smelting Company of Canada (COMINCO) were written from 1917 to 1919 by P. Kirkegaard, in 1933 by W.J. Mead and A.E. Jure, and from 1936 to 1937 by C.A. Seaton, and provide good details of the ore zones at Cordova. These records and more recent mapping, permit some inferences to be made of structural influences on the veins and pay shoots.

Figure 2 is a sketch of the Cordova Gabbro simplified from Thomas and Cherry (1981). The strike attitude of primary foliation in the outer zone of foliated gabbro, the shape of the body, and the boundary relations, seen both from Bartlett's (1982) map and on the ground, suggest that the gabbro is block-faulted, and that the barren easterly section is at a different structural level.

Strike and dip observations from old records imply that the orebodies at Cordova were pipe-like structures at the intersection of 2 shear directions dipping 65°/190° and 65°/255°. The calculated direction (Figure 2) of plunge is 65°/170°. If all known strike/dip information for these planes is plotted, a cluster of plunge intersections is given, ranging as follows: 65°/96°, 70°/130°, 70°/137°. An understanding of the structural level of the gold-bearing veins is important for correct prediction of their extent, grades, and mineralogy. The striae on shear planes reported by Thomas and Cherry (1981) plunge "45° to 60° to the south or east", but P.B. Thomas (Graduate Student, Carleton University, Ottawa, Ontario, personal communication, 1982) has been unable to establish relative displacement. This might have indicated whether the vein material filled open fracture planes in the gabbro, and given secondary evidence of the possible depth extension of veins.

Mineralogy of Gold Veins in Belmont, Madoc, and Marmora Townships

Vein mineralogy is a key factor in processes of concentration by weathering or in an ore-dressing operation. It must be considered when attempts are made to rework tailings, to heap leach, and if secondary concentrations of gold are sought.

It is evident that the gold veins of the above townships showed vertical zonation: older records (Blue 1894; Miller 1902) report visible gold from the Cordova Mine, the Ledyard Mine and the Demars vein, the Richardson Mine, and the Crescent Mine. The gold was often found in large open cavities in the veins, together with other "sparry" crystals, galena, and chalcopyrite (Miller 1902, p.191). References to a decomposed earthy oxide layer which panned free gold, to changes of mineralogy below the water table, and to increasing sulphide mineralization at depth, make it apparent that a gossan capped a layer of secondary enrichment.

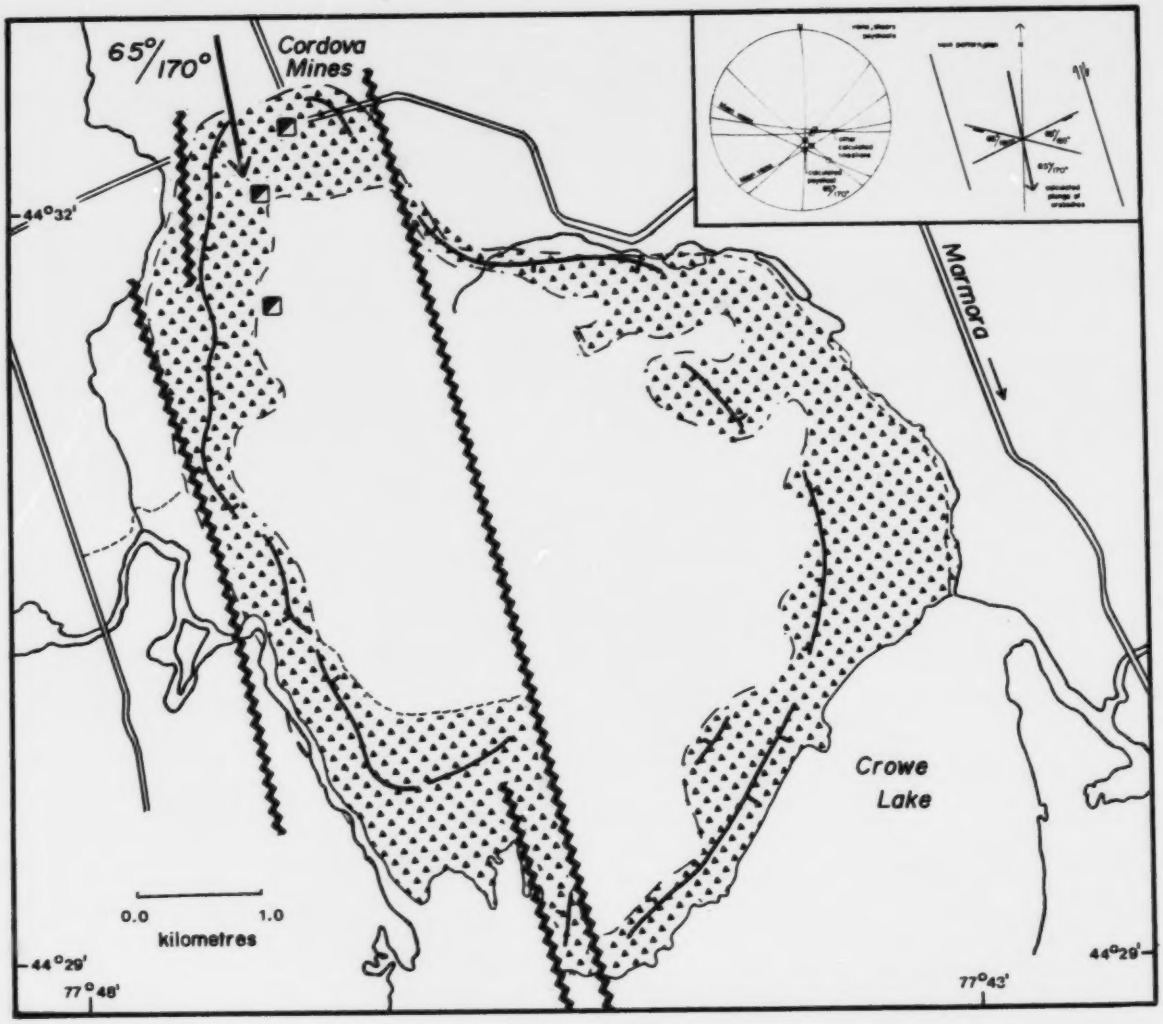


Figure 2—Geology of the Cordova Gabbro (after Thomas and Cherry 1981). Insets show structural data.

The changing mineralogy with depth of mining is evident from records of the dressing processes employed at Cordova and other local mills. When the first Cordova mill opened in 1898, grinding to – 40 mesh and mercury amalgamation (Kirkegaard 1917, COMINCO Company Report) were sufficient to treat the oxidized ores, although about $3.50 a ton were lost in the tailings (Blue 1894, p.50). By 1901, however, Cordova ores were ground to – 80 mesh and extracted by cyanide percolation. Sulphide minerals in the ore had increased from 3 to 7 percent at 500 feet.

Implications of Mineral Zones for Secondary Concentration of Gold

Surface gold from these veins was visible, coarser grained, and easily weathered, and heavy mineral concentrates should therefore be sought downstream or down-ice from the veins. Henderson (1973) recognized a deeply weathered layer up to 9 feet thick, north of Cordova Mines, which has been unaffected by glacial scour, but in general, the surface debris has been redistributed. Ice-borne deposits have been reported from the Cook Property (Carter 1902, p.234; 1903), buried under 10 feet of stratified clay. Figure 3 shows spillways, eskers, and glacial striae, all of which may point to areas of heavy mineral concentration. Quaternary mapping in progress at a scale of 1:125 000, by the Ontario Geological Survey, between Longitudes 78°W and 77°30'W, and Latitudes 44°N to 44°30'N will undoubtedly indicate other targets.

Gold is readily soluble (Boyle 1979), particularly when finely milled or derived from sub-microscopic inclusions in sulphide minerals, and is easily captured as organic complexes in humic deposits such as peat. This implies that gold may also be concentrating in swampy

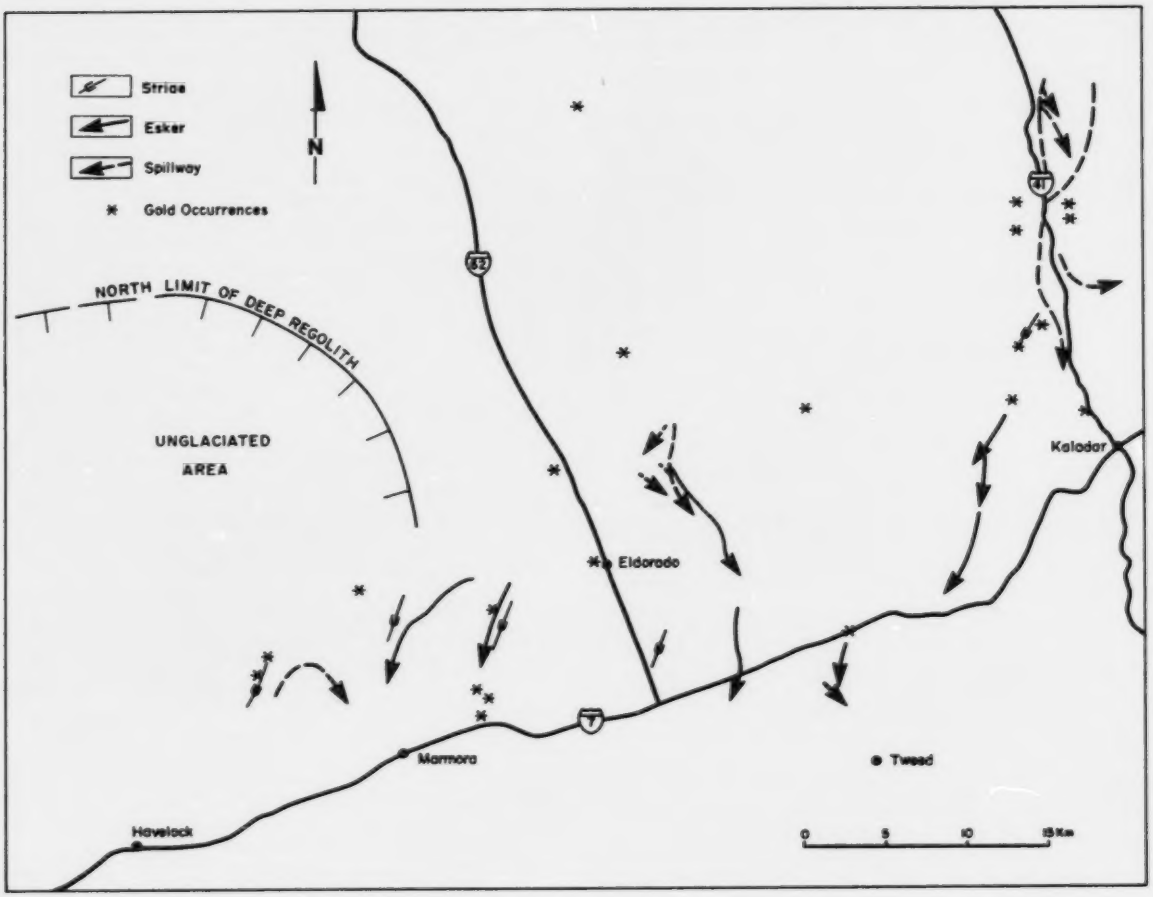


Figure 3—Glacial transport in relation to gold deposits.

areas downstream, especially where upstream a natural association with arsenical ores or milling and cyanidation have rendered it particularly soluble. The Cameron Creek swamp in Portland Township is the type of deep peat site which might be evaluated, although in this case there is no gold provenance upstream.

Mineralogical Sites for Gold

Early records show that native gold, as nuggets, grains, and leaf gold (Blue 1894, p.54), was the principal ore near the surface, but at depth the gold was contained in sulphide minerals. Accurate knowledge of the mineralogical sites for gold then becomes important for ore dressing, and for later reworking of tailings.

At Cordova, blue quartz, pyrite, and pyrrhotite were recognized as auriferous; no assays are available for quartz alone, but pyrrhotite gave consistently lower gold values than pyrite. The arsenopyrite ores at Deloro also carried gold, but the ore dressing was difficult. Miller (1902) showed that gold was present as fine inclusions in arsenopyrite, not as gold arsenates.

Assays of minerals from local gold mines are shown in Table 1.

Pyrite in the Deloro Intrusion

As pyrite is the principal host for gold in the Cordova Gabbro, its presence in the adjacent Deloro body may be economically important.

The western margin of the Deloro body hosts a number of veins which were formerly mined for gold (Carter 1980). Most, however, had minimal production, apparently because the metal was hosted by refractory arsenopyrite (Blue 1894; Miller 1902) which was more profitable for arsenic production.

The body is a composite intrusion; the western margin shows many examples of an early gabbroic phase which can be seen chilled against the overlying marble from which it has stoped fragments. The boundary relationships are well shown in marble quarries not far from the old Sovereign Mine, where flat-lying marbles are intruded by numerous sills of gabbro or its finer counterparts. A pyrite selvedge up to 1.5 cm wide is commonly developed at the gabbro margin, and veins of pyrite extend along fractures well into the gabbro itself. This margin was sampled in 1982 and the pyrite will be assayed. If it is auriferous, polished section microscopy will be undertaken to determine the physical location of gold. This mineralogy is quite different from the arsenopyrite-free gold association reported by Miller (1902) for the Deloro gold veins.

TABLE 1 ASSAYS OF MINERALS FROM LOCAL GOLD MINES

MINE	ORE	GOLD	
		oz/per ton	$ per ton
Cordova (Miller 1902)	pyrite	5-6	
	pyrrhotite		13
Ledyard (Blue 1894)	pyrite		90
	assorted ore	4.7	94
	quartz-pyrite	4.6	
Pearce (Blue 1894)	arsenopyrite		8

Reworking of Tailings

At Cordova, Carter (in preparation) reports a large amount of tailings from the milling operations. Orvana Mines Limited conducted a systematic program of measuring and sampling these dumps in 1964. Two tailings ponds were identified; one was built prior to 1918 and the other by The Consolidated Mining and Smelting Company of Canada Limited in 1939 and 1940. The ponds were sampled using a power auger. A total of 105 samples were collected from The Consolidated Mining and Smelting Company of Canada Limited tailings pond, and these averaged 0.02 ounce gold per ton. The results of the other sampling programs are presented in Table 2, and indicate a total of 21 700 tons of broken ore and tailings on surface dumps averaging 0.17 ounce gold per ton (H.G. Harper, unpublished geological report for Orvana Mines Limited 1965).

Carter also states that Lasir Gold Incorporated has recently estimated that the ore dumps contain approximately 15 000 to 20 000 tons containing about 0.06 ounce gold per ton. Approximately 1000 tons of tailings were outlined by the company which were estimated to contain an average of 0.33 ounce gold per ton based on surface sampling of the pond. A small tonnage of tailings was test milled on the mine-site in a small pilot plant with recovery of a concentrate consisting of about 800 pounds of charcoal grading 151 ounces gold per ton (Walter Hood, Lasir Gold Incorporated, personal communication, 1982).

Carter was able to identify and sample the newer pond, which presumably dates from 1939 to 1940; analyses are given in Table 3.

In 1982 the author was able to trace the older tailings pond, which probably dates from 1897 to 1903; it is visible on air photographs (Figure 4). On the ground, it is marked by a thin tree cover of balsam, poplar, and birch; at the pond edge, white cedar, white spruce, and tamarack have regrown. The herbaceous vegetation of the pond includes plants tolerant of very acid or sharply-drained sites. They are listed below:

Downy Goldenrod *(Solidago puberula)*
Gray Goldenrod *(Solidago nemoralis)*

TABLE 2 COMPOSITE SUMMARY OF RESULTS OF SAMPLING OF SURFACE DUMPS AND TAILINGS PONDS BY ORVANA MINES LIMITED (H.G. HARPER, UNPUBLISHED REPORT FOR ORVANA MINES LIMITED, 1965)

	Tailings Pond	No. 3 shaft	No. 1 shaft
Number of samples	–	120	193
Estimated tonnage	6400	6500	8800
Average grade (oz/ton Au)*	0.144	0.200	0.164

*values are from Carter (in preparation)

Slender Fragrant Goldenrod *(Solidago tenuifolia)*
Swamp Fly Honeysuckle *(Lonicera oblongifolia)*
Field Horsetail *(Equisetum arvense)*
Russian Thistle *(Salsola pestifer)*
Orange Hawkweed *(Hieracium aurantiacum)*
Blueweed *(Echium vulgare)*
Rush *(Juncus sp.)*
Sweet White Clover *(Melilotus alba)*

The tailings have again been sampled and will be examined both by assay, and as grain mounts to determine movement of gold in the wastes. A visible hard pan indicates a new gossan may be forming through subaerial weathering processes.

Field examination of the ore pile shows that the magnetite concentrates (Table 1) derive from the Cordova Gabbro itself; primary segregations of heavy minerals can be seen on the northern margin of the body, and near the east contact (Thomas and Cherry 1981). In this case, a primary magnetic separation would further concentrate the gold-bearing wastes.

Conclusions

1. In the Kaladar area the gold-bearing quartz veins commonly found near the Flinton Unconformity are located in shear structures at the margins of steeply dipping, narrow synclines. The structure itself rather than the unconformity is the principal control. Mineralized veins preferentially replace mafic rocks or their sheared equivalents.

TABLE 3 TAILINGS ANALYSES (FROM CARTER 1981). THE POND PROBABLY DATES FROM 1939–1940.

	Au (oz/ton)	Au (oz/ton)
Magnetite-rich sand	0.69	trace
Oxidized magnetite sand	0.11	trace
Yellow, magnetite-free sand	–	0.14

2. The Cordova Gabbro is block-faulted, and gold-bearing quartz veins are confined to the western part which is at a different structural level. The veins are enriched at shear intersections; payshoots are calculated to plunge steeply southeast.
3. Gold-bearing quartz veins around Marmora show mineral zoning; the early discoveries found an enriched layer with a gossan in which coarse, free gold was common. Unless veins of this kind are hidden below a drift cover, it is unlikely that the high-grade material of former times will be available. At lower levels in the veins, gold is contained in sulphide minerals, principally pyrite and pyrrhotite. If gold in this association is to be economically profitable, the mineralogy of the ores and the physical location of the gold in sulphide mineralization must be carefully examined.
4. Free gold concentrated secondarily from the supergene horizon may exist. Quaternary mapping has shown a thick fossil soil, untouched by glacial action, lying northeast of Cordova Mines. Elsewhere, glacial spillways and esker trains suggest areas southwest of the veins in which gold may be concentrated. Furthermore, gold, in organic combination, may be accumulating in swamp areas downstream.
5. Pyrite is the principal host of gold in the Cordova Gabbro; assays show that pyrrhotite and blue quartz are also auriferous. In the adjacent Deloro "granite",

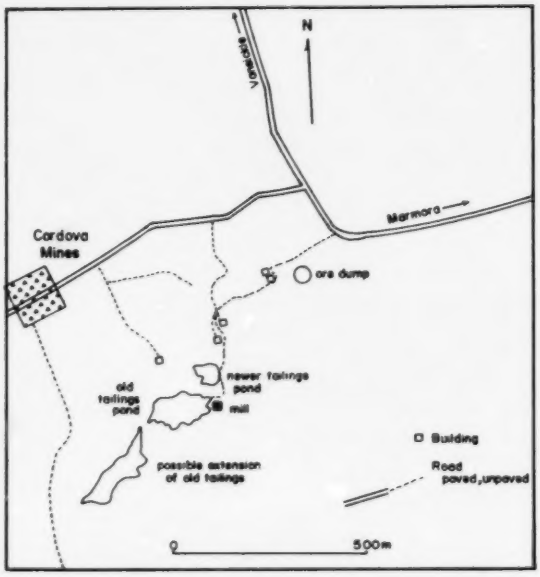


Figure 4—Cordova Mine tailings ponds.

arsenopyrite is the gold-bearing mineral. A new find of pyrite, formed as selvedges at the contact between Grenville marble and a gabbroic phase of the Deloro body, has been sampled. If auriferous, it may suggest a new source for ore.

6. Tailings from two ponds at the Cordova Mine show significant assay values. Hard-pan development suggests that a new gossan is forming; samples will be examined for movement of gold in solution. The older tailings pond (1893 to 1903) can be traced on the ground by vegetation changes. Magnetic separation of magnetite concentrations, derived from the gabbroic host rocks, would upgrade the gold-bearing fraction.

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No. 34 Graphite and Other Carbon-Rich Minerals in Rocks of Grenville Age

Janet S. Springer[1]

Introduction

Recent work in the Grenville Subprovince (Storey and Vos 1981; Carter 1981; Papertzian and Kingston 1982; Davidson and Morgan 1981; Davidson *et al.* 1982) has drawn attention to the economic possibilities of graphite. An understanding of the mechanisms of primary and secondary concentration then becomes necessary for correct forecasting of deposits of workable size. In addition, the formation of the mineral or its precursors, has a direct bearing on possible associations of accessory or trace elements, which themselves may be of economic significance.

Carbon can occur in poorly crystalline or amorphous form, and as the lattice-ordered form, graphite. Davidson (Davidson and Morgan 1981; Davidson *et al.* 1982) assumes the graphite to be organic in origin; Carter (1981) has argued for sedimentary concentration of organic material at contacts which mark the transitions from carbonate to clastic sedimentation. Storey and Vos (1981) have discussed abiotic methods of producing elemental carbon by the destruction of carbonate minerals; they suggest, in addition, that small amounts of carbonaceous material, surviving from a black-shale environment of deposition, may have seeded secondary concentrations

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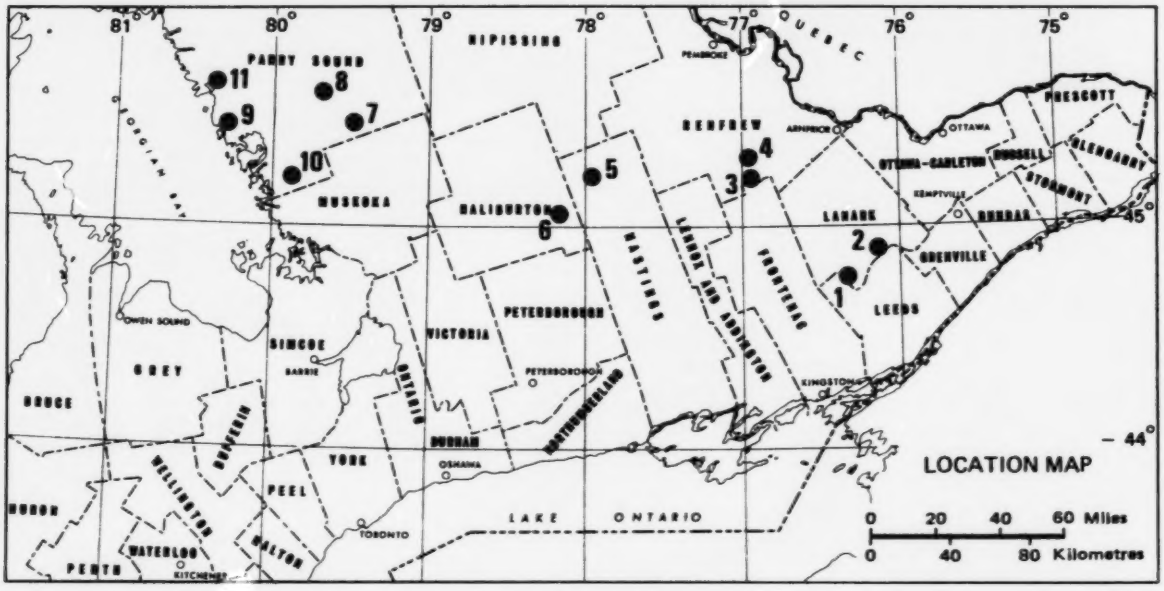

LEGEND

Graphite

1 Globe Mine
2 Timmins Mine
3 Black Donald Mine
4 Carter Lake Property
5 Tonkin Dupont Mine
6 National Graphite (Cardiff Tp.) Mine
7 Emsdale Occurrence
8 Magnetawan Occurrence
9 Pointe-au-Baril Occurrence

Thucolite

10 Conger Tp. Occurrence
11 Besner Feldspar Quarry

of graphite. Hewitt (1965) and Spence (1920) deduced a metasomatic replacement origin for graphite orebodies.

However, there are also tarry or oily hydrocarbons, with carbon contents of 50 to 80 percent, found in pegmatites (Obalski 1904; Ellsworth 1928; Spence 1930) in the Grenville Province. As hydrocarbons are commonly considered to be distillates from buried organic matter, and as analyses of some of these "thucolites" (Ellsworth 1928) show over 2 percent vanadium, an element which varies sensitively with organic carbon content (Hirst 1974), the carbon minerals of these pegmatites may provide clues to the presence of micro-organisms in the Precambrian, and add factual evidence to the discussion of the origins of this graphite.

Present Study

This summer, 6 graphite deposits in the Central Metasedimentary Belt, 3 from the Central Gneiss Belt, and 2 thucolite occurrences have been examined, as shown on the Location Map. This information adds to data collected in 1981 from the Kirkham graphite Deposit, and to Carter's (1981) report from the same locality.

Working assumptions have been that if graphite is a sedimentary accumulation:

1. its initial concentration will fall into the normal range for present-day sediments
2. that its distribution will show stratigraphic patterns
3. that, where the stratigraphy is interrupted by gross structural breaks, patterns of difference or similarity in graphite deposits from one structural domain to another may throw light on mechanisms of secondary concentration

Major Structural Elements

Work by Davidson and Morgan (1981), Davidson *et al.* (1982), Schwerdtner and Mawer (1982), Bright (in preparation), Wynne-Edwards (1965), and other older studies have pointed out major structural dislocations in the Grenville Subprovince. Scattered field observations in 1982 by the author, and inferences that can be drawn from already-published maps and reports, indicate that major zones of displacement that can now be identified shape the broad outlines of Grenville stratigraphy, and are essential to understanding the present disposition of rocks. This is clear from work in the Ontario Gneiss Segment, to the northwest (Figure 1), where Davidson *et al.* (1982) have recognized a mosaic of thrust slices, dipping gently southeastward, which have been overthrust to the northwest; the slices vary in both lithology and metamorphic grade.

Farther east, within the Central Metasedimentary Belt, similar patterns can be inferred, although there is not yet sufficient evidence to show that these structural lines also mark strong differences of metamorphic grade. Map sheets by Bright (Eels Lake, 1 inch to 1 mile; Burleigh Falls, 1:50 000, in preparation, 1982) show curvilinear planes of overthrusting, dipping southeast; these long-lived movement planes have affected deposition into Paleozoic time, and been reactivated thereafter. Other examples, whose strike orientation is similar and which dip southeast, are the Robertson Lake fault mapped by Peach (1958), and the Desert Lake thrust fault shown by Wynne-Edwards (1965).

In the field, evidence for dislocation is often clear, particularly when high-grade rocks are affected by mechanical disruption. Textures which characterize mylonites at the sole of the Moon River thrust sheet can be closely matched to similar rocks on spur branches of the Derry Lake fault on Highway 500, at the northern turn to Maxwell settlement (Masson 1982), or on the shores of Lower Cardiff Lake, east of Wilberforce. However, in lower grade rocks, particularly where the principal motion is a strike-slip displacement, the importance of the structure may be disguised by its trivial field expression. The Robertson Lake fault is of this kind, and structural evidence from the Flinton-Kaladar area (see Springer, this volume) suggests that fault structures, oriented N10° to 30°E, which influence the northerly trend of the synclines between Bishop's Corner and Flinton, are of regional significance even though they are poorly marked in the field. A sinistral displacement can be inferred for the Kaladar and Robertson Lake zones, which together with a sense of over-riding to the northwest, may prove to be a general feature of these dislocations.

Metamorphic Grade

Broadly, the metamorphic grade of the Central Metasedimentary Belt steps up eastward and westward from a low-grade area near Madoc. The known correlation between the transition to graphite, and rising metamorphic grade, means that significant graphite deposits are not found in low-grade areas, although amorphous carbon is plainly evident in the marbles and pelitic schists.

Carbon Content

Storey and Vos (1981) have carefully described 24 graphite deposits from the Pembroke-Renfrew area; 18 deposits, in part overlapping Storey and Vos (1981), are summarized by Papertzian and Kingston (1982), who tabulate a further 36 examples. Dillon and Barron (this volume) give recent descriptions of the National Graphite (Cardiff Township) Property, the Virginia graphite area in Monmouth Township, and the graphitic marbles in Olden Township. In addition, 7 localities in the Central Gneiss Segment, located in different thrust sheets, have been examined in 1982 by the author. Of all these deposits, only 10 show graphite concentrations which reach or exceed 20 percent carbon. The amounts, up to this level, fall within the expected range for normal sedimentary rocks (Degens and Ross 1974).

Limited grab samples from the Butt Township graphite Deposits have given assays of 0.7 to 5.74 percent carbon, determined by LECO analysis (D. Villard, Resident Geologist, Ontario Ministry of Natural Resources, Huntsville, personal communication, 1982). These values are still interesting commercially because of the large strike extension and good widths on these stratiform bodies.

Secondary Concentration of Graphite

Recrystallization

In the high-grade metamorphic rocks which can be seen at the National Graphite Property in Cardiff Township, recrystallization of graphite to a coarser flake gives the appearance of increasing its percentage. The small flakes 1 to 2 mm across, which are evenly distributed through the banded quartz-biotite schists and amphibolites, can be seen forming a selvedge of flakes 4 to 5 mm across at the margins of concordant vein-like quartz-potash feldspar segregations; graphite does not occur at the centre of these bodies. This relationship has formerly been interpreted as indicating a hydrothermal origin for the graphite; it could as well be explained as partial anatexis and recrystallization of the mineral from its host rocks.

Structure

The Black Donald, the Kirkham, the Bawden, the Tonkin-Dupont, and the Globe graphite Deposits, all show concentrations of graphite above the 10 percent range; they also show increasing amounts of graphite in the crests of folds. Spence (1920) has commented on this at the Globe graphite Mine; it is also evident from reports of the Black Donald Mine, and Carter (1981) mentions the association at the Kirkham graphite Deposit. Figure 2 shows a reconstruction, modified from Spence's (1920) figures.

Figure 2 which shows the Kirkham-Bawden Deposits combines information from Wynne-Edwards (1965), Carter (1981), and from mine data illustrated by Hewitt (1965). It shows that the Bawden graphite Deposit lies on the eastern limb of a synformal structure plunging northeast, and that the richer Kirkham graphite body is at the nose of an earlier synformal structure, also plunging northeast, which is cut off westward against the Desert Lake fault.

The Globe graphite Deposit is shown in Figure 3, compiled from data by Spence (1920). There again, reported evidence suggests that folding, particularly multiple folding, results in the enrichment of graphite ore.

The Black Donald Mine is now flooded, but structural observations immediately southwest of the mine site, in

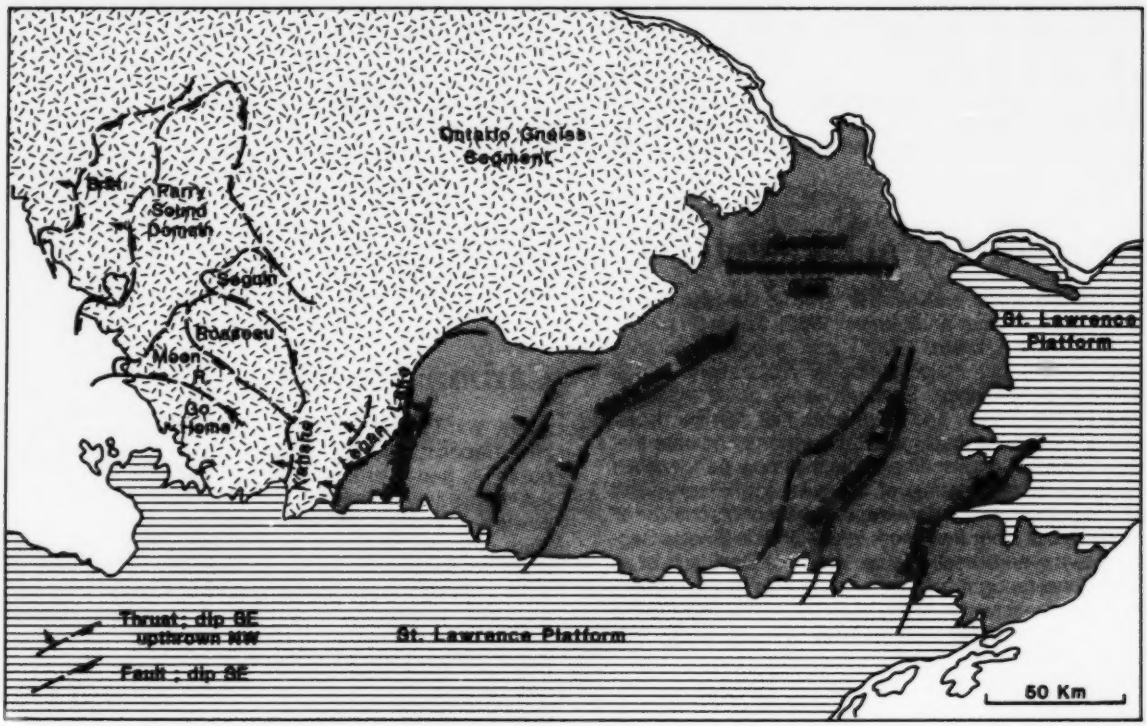

Figure 1—Major structural elements within the Grenville Subprovince.

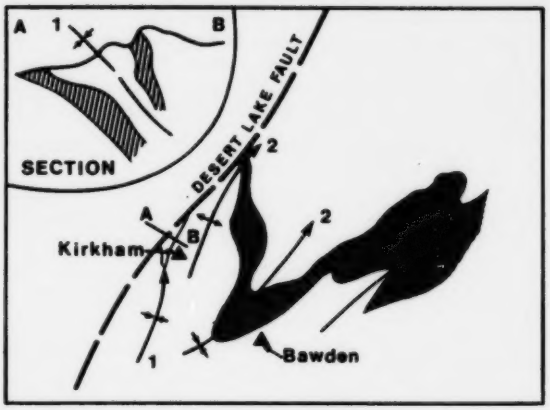

Figure 2—Structural influence on the orebody at Globe graphite Mine, modified from Spence (1920).

interbanded marbles and calc-silicate horizons, show a strongly developed pervasive rodding which plunges 18°/051°; the "dragfold structure" reported by Hewitt (1965, p.50) "plunges 20°NE". Similarly minor folds, southwest of the mine site, whose axial traces trend 040°, give a sense of movement which is consistent with the major structures shown in section A'–A (Hewitt 1965, p.48).

Examples such as these suggest that the mechanical displacements, which take place during the formation of similar folds, are sufficient to concentrate graphite, and that several phases of folding may result in elongate saddle-like or rod-like orebodies. This knowledge is obviously important in assessing the continuity of the orebodies.

Variations in Flakiness

Besides the increase in flake size that can be seen as pegmatite segregations develop, there are sharp, apparently primary, differences in the degree of crystallinity. Spence (1920) noticed this, and attributed it to secondary, mechanical crushing of coarser flake graphite. Storey (Storey and Vos 1981, p.64) has given careful descriptions of these differences from localities on the Matawatchan Road, which have been verified by the author.

Graphite is restricted to gritty biotite-quartz-feldspar horizons, and the field relationships do not suggest destruction of the graphite. Bands containing 1 to 2 mm flakes can be traced northeast along strike towards the Carter Lake graphite Property (Lumbers and Vertolli 1979; Vos and Storey 1981, p.64). They show a well crystallized regional fabric, with axial plane cleavage and a cleavage-bedding lineation, both paralleled by the graphite flakes. This fabric is folded across a younger, antiformal structure plunging northeast, which is shown on Map P.1838 (Lumbers and Vertolli 1979). In this fold the graphite flakes neither become more concentrated at the fold hinge, nor smaller in size. However, nearer the Carter Lake Property where the hinge of an even earlier structure is crossed, the host rocks begin to include calcitic marbles. Sooty graphite horizons appear with abundant pyrite and pyrrhotite, separated across strike by only 5 to 10 cm from flake graphite horizons. The presence of "amorphous" graphite is reported by Storey and Vos (1981) from the Beidelmann-Lyall, the McDonald's Lake, the Carter Lake, the Little-Bryan, the Black Lake, and the Black Donald Properties.

Reports and field observations suggest that there is a correlation between the presence of sulphide mineralization, and some instances of poorly developed flake, but the relationship is still ambiguous.

Field Markers for Graphite

Rusty weathering, developed from the oxidation of sulphide ores, is often present as a field marker, but it is not diagnostic of graphite alone. More characteristic is a pale yellow coating, typically on a friable weathered surface, which may penetrate 10 to 20 cm into the rock face. This yellow mineral is jarosite (X-ray analysis, Geoscience Laboratories, Ontario Geological Survey, Toronto, 1982), a member of the alunite group of hydrated iron sulphates. Potash-rich, soda-rich and ammonia-rich jarosites exist in nature but closer identification has not been made at this stage.

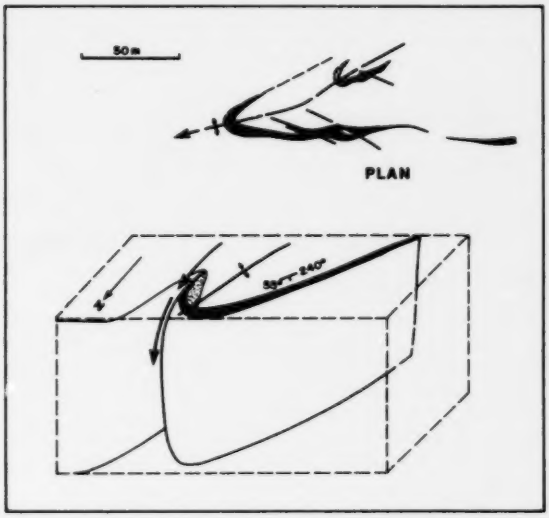

Figure 3—Structural inferences; Kirkham and Bawden graphite Deposits.

Host Rocks

Graphite flake has been observed in biotite schists, in amphibolites, in marbles, and marginal to quartz feldspar pegmatites. The mineral does not appear preferentially associated with a given lithology, although amphibolites bearing graphite are not common. The overall appearance of these concentrations suggests primary sedimentary accumulation. Storey and Vos (1981) considered some of the rocks in the Renfrew area to be arkoses, on the basis of thin section examination. In the Central Metasedimentary Belt, marbles are frequently present nearby. This may be the expression of a particular environment, which is required for graphite formation; however, graphite horizons of the Central Gneiss Segment do not show associated marbles, and so there is presumably no simple connection between carbonate sedimentation and carbon accumulation.

Trace Elements Associated with Graphitic Horizons

Copper, zinc, lead, nickel, and cobalt have been reported from these graphite bands by Carter *et al.* (1980), Storey and Vos (1981), and other authors. Interest has been expressed in the association of gold with graphite in the Butt Township deposits, but assays of grab samples (D. Villard, Resident Geologist, Ontario Ministry of Natural Resources Huntsville, personal communication, 1982) have not shown more than a trace. Other samples collected systematically across the Central Metasedimentary Belt still await analysis. The highest values reported so far for gold (Storey and Vos 1981) are 20 parts per billion (Allanhurst Property), and 10 parts per billion (Beidelman-Lyall Property).

Elevated values for vanadium and boron, reported for several localities in the Pembroke-Renfrew area (Storey and Vos 1981) are interesting because of the known affinity of these elements for organic carbon (Hirst 1974); increased levels of mercury are remarkable because the element is uncommon, and is not normally preferentially enriched in the organic fraction of sediments.

Carbonaceous Minerals other than Graphite: Thucolite

Two localities from which thucolite has been reported in pegmatites (Ellsworth 1928; Spence 1930) are shown on the Location Map. This radioactive mineral may be important in understanding the tripartite association of gold, graphite, and uranium, which is well documented from the Witwatersrand (Minter 1976), and, to a lesser degree, from detrital uranium deposits at Elliot Lake (Robinson 1982).

The Besner feldspar Quarry from which an oily hydrocarbon was reported in 1930, is now water-filled and all that remain are scattered heaps of glassy quartz and coarse-grained perthitic potash feldspar. It seems unlikely from the clear vitreous appearance of the quartz that any radioactive species were present. There is no trace of the semi-liquid hydrocarbon reported from here by Spence (1930) or its waxy oxidation products.

The Conger Township thucolite locality (Ellsworth 1928) is now overgrown. A cottage road from Highway 69 north of Hamer Lake runs west toward Oldfield Lake. It is shown on the Muskoka NTS sheet (31 E/SW). Mapping was aided by a Scintrex scintillometer.

The host rocks, which form part of the Moon River tectonic domain, are amphibolites. They are cut by conformable lenses of quartz-biotite-potash feldspar pegmatite which give 5x, 10x, and 250x background levels, depending on the mineralogy.

Close to the eastern shore of Crane Lake, an old quarry about 20 m across and 10 m deep shows coarse microcline-quartz pegmatite, with biotite-rich patches giving readings of 1000x background. This material is presumably thucolite-bearing, and has been sampled for further analysis.

Conclusions

1. Graphite in Butt and Armour Townships, within the Central Gneiss Segment, is economically interesting where it promises considerable strike extension and a good thickness; grab samples range from 1 to 5 percent carbon.
2. If these deposits are stratiform and strike length is important, it becomes vital to understand the gross structural features of the region.
3. Recent work enables a pattern of thrust slices, riding northwest on north- to northeast-striking dislocation planes, to be identified across both the Central Gneiss Segment and the Central Metasedimentary Belt.
4. Locally, in the Central Metasedimentary Belt, primary variations of graphite with host rock and in graphite flake size can be identified.
5. The graphite content, overall, falls into the range expected of sedimentary rocks.
6. Concentrations of more than 20 percent graphite are commonly found to be controlled by fold structures. It is suggested that the mechanics of similar folding is sufficient to cause this upgrading, which is even more effective after multiple fold episodes. Saddle-like or rod-like orebodies are the result.
7. Jarosite, a hydrated iron sulphate is a rapid field indicator of the presence of graphite.
8. Nickel, cobalt, copper, zinc, and lead are trace associates of graphite. The highest gold values so far are 10 to 20 parts per billion. Elevated values for vanadium and boron suggest an organic origin for the carbon; elevated readings for arsenic and mercury are noteworthy but ambiguous, so far.

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No. 35 Industrial Minerals Studies

M.A. Vos[1]

Introduction

Staff of the Mineral Deposits Section in conjunction with the Regional Offices of the Ontario Ministry of Natural Resources, were active in 1982 in programs to identify and assess potential sources of a large number of industrial minerals and commodities, including calcium carbonate, barite, nepheline syenite, feldspar, silica, talc, graphite, phosphate, kaolinite, peat, and building stone. These programs include continuing industrial minerals programs of the Mineral Deposits Section, and programs of the Northern Industrial Mineral Studies (NIMS) program, funded by the Ontario Ministry of Northern Affairs, and are discussed in this summary under these broad headings

Industrial Minerals Studies in the Mineral Deposits Section

Nepheline Syenite and Feldspar in Northern Ontario

As part of a continuing program to evaluate nepheline syenite and feldspar resources in northern Ontario (Vos 1980a), whole rock analyses have been obtained for rock types in the vicinity of the nepheline syenite complex in Bigwood Township, 55 km southeast of Sudbury (Figure 1). Steep Rock Iron Mines Limited have recently carried out a diamond-drill program in parts of this complex (information available in the Assessment Files Research Office, Ontario Geological Survey, Toronto). The analytical data show (Table 1) the low iron content of the nepheline syenite, particularly the pegmatitic phase (Sample A), and the feldspathic sandstone (Sample D), in comparison to the feldspathic gneiss (Sample C). The alkalic ratio favours Na_2O in the syenites and K_2O in the feldspathic sandstone. Additional analyses are required to characterize changes in composition in the complex that might result from addition of alkalies and/or subtraction of silica and iron, which would aid in determining the genesis of the nepheline syenite.

Carbonatite-Alkalic Complexes

Studies of the industrial minerals of carbonatite-alkalic complexes in Ontario were initiated as a NIMS project in 1979 (Vos 1980b, 1981) and are now a continuing program of the Mineral Deposits Section. Most recently, the Martison complex, 80 km north-northeast of Hearst has been investigated. This complex was originally outlined as a magnetic anomaly (Satterly 1968), and later was suggested by Sage (1979, p.73) to be a potential source of niobium and apatite. It has subsequently been explored by Shell Canada Resources Limited. The results of this program, which included sonic and reverse-circulation drilling, have not been made public, but the company has made available preliminary ore reserve estimates of 140 000 000 tons of 20 percent P_2O_5; 0.35 percent Nb_2O_5; and as yet undetermined values in rare earth minerals. Some deeper pockets of ore were found to contain up to 39 percent P_2O_5 in the irregular karst topography of the carbonatite.

Silica (Sand)

Demand for silica sand and a difficulty in obtaining ready supplies at competitive rates from sources in the United States augur well for development of Ontario's resources of this commodity. Recent programs of the Ontario Ministry of Natural Resources to assess silica resources include studies of Cambro-Ordovician sandstones in eastern Ontario (Powell and Klugman 1979; Klugman and Yen 1980), and investigations by the author of the Sylvania sandstone in the Windsor area, Recent sands of the Campement d'Ours area on the northern shore of Lake Huron, and the Cretaceous sands of the James Bay Lowlands. The extent and quality of sand deposits along the northern shore of Lake Huron, which could be dredged and transported by barge, should be investigated.

A quartz sand deposit near Westree, north of Sudbury, will be evaluated for its silica potential under the auspices of the Northern Ontario Rural Development Agreement (NORDA). Outwash sands in this area are potential sources of silica and foundry sand.

Building Stone

Renewed use of facing stone in construction and continued uses in the monument industry are reflected in the increased search for sources of these materials. New developments in cutting and polishing equipment are changing the economics of this industry. During the 1982 field season, the author completed a program of examining and sampling active and abandoned granite quarries in eastern Ontario. Samples from this program will form part of a display set of potential building stone resources,

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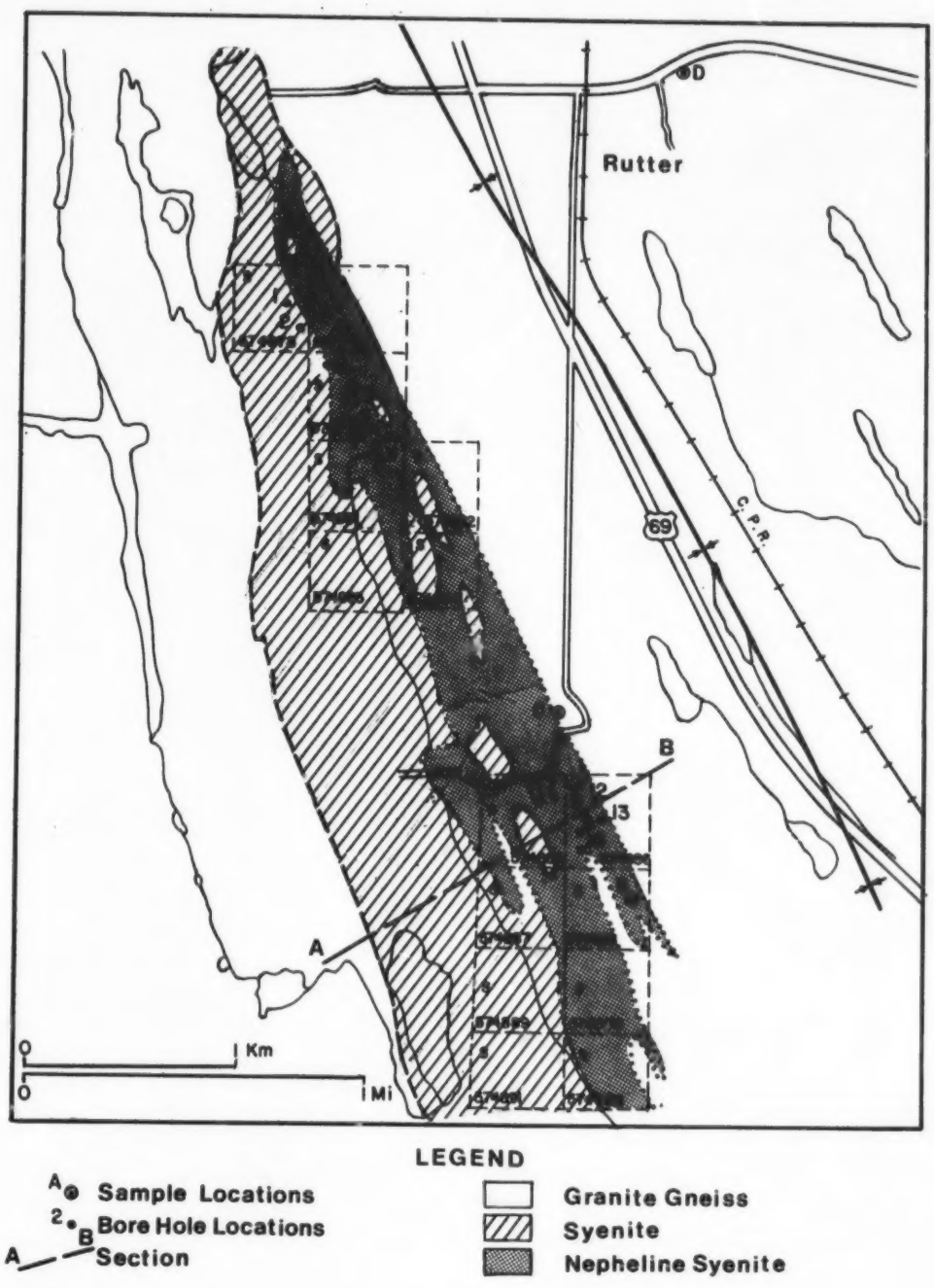

Figure 1—Northern part of French River nepheline syenite, Bigwood Township

which also includes cut and polished cobbles and boulders from beaches on the northern shore of Lake Superior. Beaches near Marathon, underlain by the Coldwell Complex, provide cobbles of many rock types that appear suitable for building stone. The rock types of the Coldwell Complex are distributed concentrically about a centre that has shifted at least twice (Currie 1980), and the accompanying protracted high temperature regime and metasomatism may have produced exceptionally homogeneous and strain-relaxed crystalline rocks.

Industrial Minerals in Eastern and Southern Ontario

Canadian Talc Industries Limited have outlined a new deposit on their Madoc Property, to the south and parallel with the previously mined Henderson orebody; this new deposit is estimated to contain 1 000 000 tons of talc ore, to a depth of 183 m (600 feet).

A potentially economic mica deposit has been discovered in grey, muscovite-garnet metasedimentary schists in Kaladar Township. The mica zone, in which mica flakes comprise an average 50 percent of the rock, is 60 to 90 m wide; the schist extends approximately 3 km in a northeasterly direction, and dips at a moderate angle to the south.

Exploration of a previously known graphite deposit in Butt Township, near Huntsville (Hewitt 1965, p.40) by Vesuvius Crucibles has established a mineralized zone about 3000 feet long.

Talc and graphite in Southern Ontario are the subjects of a separate study by the Mineral Deposits Section (see Dillon and Barron, this volume).

Northern Industrial Mineral Studies (NIMS)

Sources of Lime in Northwestern Ontario

A recently completed study of lime in northwestern Ontario by the author, and A.A. Speed and J.K. Mason of the Thunder Bay Regional Office, Ontario Ministry of Natural Resources, has identified 4 potential sources: calcite (barite) vein deposits; limestone; marl (travertine/tufa) deposits; and carbonatite-alkalic complexes. Of these, the known limestone deposits have less potential as many are overlain by great thicknesses of diabase.

Geochemical Exploration for Lithium

A study of methods of geochemical exploration for lithium has been completed by R.J. Stevenato. This study evaluated the potential of lake-centre samples as a geochemical exploration tool and utilized samples collected in a joint Federal-Provincial Uranium Reconnaissance Program. The study concluded, after extensive statistical analysis of the data, that lake sediment geochemistry is not an acceptable method of exploration for rare element

TABLE 1 CHEMICAL ANALYSES OF TYPICAL ROCK TYPES, BIGWOOD TOWNSHIP* (SAMPLE LOCATIONS ARE SHOWN ON FIGURE 1)

	A	B	C	D
SiO_2	62.4	58.9	64.4	78.1
Al_2O_3	22.1	23.9	14.8	12.5
Fe_2O_3	0.06	0.53	3.12	0.32
FeO	0.49	0.49	2.59	0.49
MgO	0.00	0.00	0.71	0.01
CaO	0.13	0.89	1.94	0.29
Na_2O	8.67	11.3	5.84	3.20
K_2O	5.30	2.87	4.86	4.73
TiO_2	0.01	0.02	0.73	0.15
P_2O_5	0.00	0.00	0.13	0.00
MnO	0.03	0.03	0.12	0.05
CO_2	0.22	0.06	0.23	0.05
S	0.	0.	0.	0.01
H_2O^+	0.39	0.30	0.36	0.27
H_2O^-	0.04	0.05	0.07	0.07
L.O.I.	0.7	0.5	0.2	0.1
Total	99.9	99.4	100.2	100.3

A – Nepheline syenite pegmatite, light grey
B – Nepheline syenite, medium grained, buff white
C – Syenite gneiss, medium grained, red, indistinctly foliated
D – Feldspathic metasandstone, fine grained, pink; metasandstone occurs in section of near-massive paragneiss in mirror position with nepheline syenite in Rutter syncline

*Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

pegmatites that might be sources of lithium, rubidium, cesium, tin, or tantalum.

Sectoral Inventory of Industrial Minerals in Northern Ontario

This inventory, to be completed in stages, will facilitate the search for industrial minerals in northern Ontario. The first of two Open File Reports, containing detailed information and references for individual occurrences, has been released (Vos *et al.* 1982), and the second is in preparation. These reports will be complemented by a catalogue of known deposits, listed geographically by divisions of the National Topographic Series maps.

Bore Hole Mining of Silica Sand-Kaolinite Feasibility Study

This project, to be completed in the autumn of 1982, is designed to assist in finding economic methods of underground mining of deeply buried silica sand-kaolinite clay deposits in the James Bay Lowland. Modern equipment, capable of lifting a payload of 30 percent solids to a height of 600 feet, has been successfully operated in mining sandstone-hosted uranium deposits. Derry, Michener, Booth, and Wahl hold the contract for this feasibility program.

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No. S20 Geology of Selected Industrial Mineral Occurrences, Southern Ontario

E.P. Dillon[1] and P.S. Barron[1]

THIS PROJECT WAS PART OF THE SOUTHEASTERN ONTARIO GEOLOGICAL SURVEY (SOGS) WHICH WAS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION (DREE) AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

The 1982 Mineral Deposits Section's component of the Southeastern Ontario Geological Survey Program (SOGS) consists of a one-year project concentrating on the geology of selected industrial minerals in southern Ontario. Following literature research, industrial mineral producers in the area were visited. The commodities chosen for study were graphite and talc, for which there is an apparent potential in this area but an inadequate data base; both are presently of interest to the mining industry. Reconnaissance field work resulted in the selection of 3 areas for each commodity for detailed mapping and sampling (Table 1).

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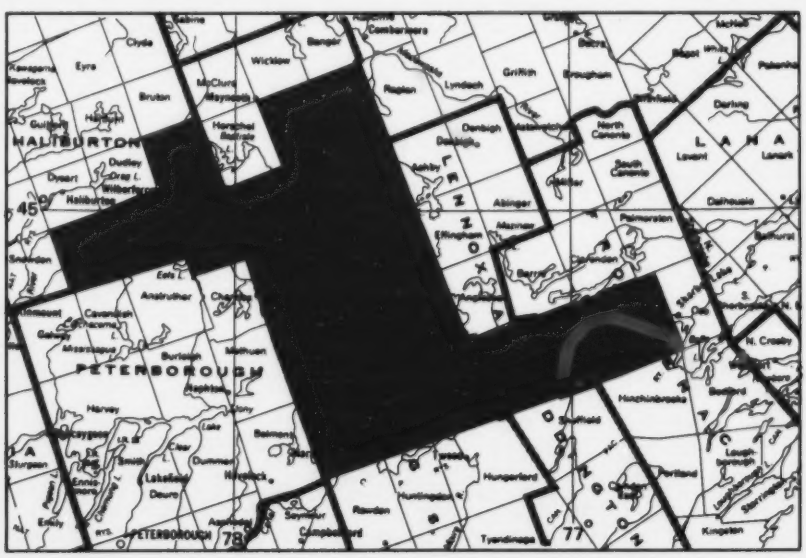
Method

In each of the detailed study areas, geological mapping and bedrock sampling were undertaken, on scales ranging from 1:5000 to 1:15 000, on flagged grid lines of 50 to 300 m spacing. Suites of rocks collected in each of the areas will be studied mineralogically and chemically in order to suggest controls on concentration of mineralization, and provide guidelines for further exploration. Sample density varied from area to area depending on outcrop, lithologic variation, and the commodity under study. Table 1 shows the number of samples collected at each locality; talc samples will be analyzed for major elements, and graphite samples for total carbon.

The following discussion of each area is based solely on field observations.



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

Talc

Madoc Talc and Mining Occurrence, Cashel Township

Access to the Madoc Talc and Mining Occurrence area is by a forest access road which runs north off the Weslemkoon Lake road at a point approximately 16 km east of the Village of Gunter. This occurrence is marked as Property 6 on Ontario Department of Mines, Map 2142 (Lumbers 1968).

This property was originally staked in 1937 by J.S. Reeves of Madoc, and exploration work was conducted by the Madoc Talc and Mining Company Limited in 1938 (Sinclair *et al.* 1940; Spence 1940). Exploration work in 1938 included sinking a 90-foot shaft on the main talc outcrop (lot 17, concession XII), driving a 50-foot cross-cut at the 85-foot level, and 125 feet of drifting on the main talc zone. The following description of the underground workings is taken from Spence (1940, p.76):

Inspection of the workings and material hoisted showed the deposit to consist of a vertical band, apparently at least 50 feet wide, made up of a greenish, rather fine-grained, chloritic talc schist. The band has suffered considerable shearing, with the development of thin layers or sheets of more highly talcose material. Within the schist lie some masses of a hard, dense, black rock, which may be of an intrusive nature, or which are possibly unaltered intercalated members of the original schist complex.

In its general character, the talcose material rather resembles that of the "grit rock" of the talc deposits of the Waterbury district, in Vermont: it is of variable mineral composition with zones containing considerable carbonate (dolomite) in fairly coarse grains, while semi-chloritized, fibrous hornblende is abundantly present as small knots in some bands. In part, the rock is of a soapstone, rather than a foliated talc, nature, and this type might perhaps serve for sawing into blocks. Selected samples of the cleanest talc yielded a powder having good slip but of off-colour grade: run-of-mine material showed a considerable grit content and would probably only be suitable for the trades employing lower grade, grey talc, such as the rubber and roofing industries.

An analysis of a sample of the crude talc from this deposit, made in the laboratory of the Bureau of Mines, showed:

Silica	40.08
Ferrous oxide	3.70
Ferric oxide	1.87
Alumina	1.75
Lime	4.85
Magnesia	29.81
Carbon dioxide	13.45
Water above 105°C	4.12
Total	99.63

This would indicate a rather large content of dolomite, and the amount of iron present (in part as magnetite) is much above that of a good commercial talc.

Lumbers described the regional geology of Cashel Township and briefly discussed the Madoc Talc and Mining Occurrence (Lumbers 1968, p.45).

The geology of the northwestern quadrant of Cashel Township consists of a narrow (3 to 5 km wide) belt of intermediate to mafic metavolcanics which have been intruded by a large trondhjemite/granodiorite batholith (Weslemkoon Batholith). Along the contact a discontinuous narrow (300 to 500 m) zone of gabbroic to dioritic rocks ("contaminated gabbro-diorite", Lumbers 1968, p.23) forms a boundary or contact zone between the metavolcanics and the felsic intrusion.

Talc-rich zones, varying in width from 8 cm to 35 m, occur in the mafic metavolcanics within 200 m of the gabbro-diorite contact zone. They form 15 to 75 m long discontinuous lenses and bands lying parallel to sub-parallel to regional foliation directions (160° to 220°) and dipping steeply (65° to vertical) to the west.

The mafic metavolcanics consist of fine-grained, massive to poorly foliated, dark green-grey to black amphibolites with quartz and quartz plagioclase porphyroblasts. These rocks are cut by secondary, fine(±1 cm),

TABLE 1 DETAILED STUDY AREAS (LOCATIONS ARE SHOWN ON FIGURES 1 AND 2)

AREA	COMMODITY	LOCATION	TOWNSHIP	NUMBER OF SAMPLES
Madoc Talc (1)	Talc	Lot 16 and 17 Con. XII	Cashel	255
Dubblestein Prospect (2)	Talc	East of McRae	Cashel	57
Cooper Area (3)	Talc		Madoc	127
Olden Township (4)	Graphite Marble	South of the Village of Mountain Grove		5
Monmouth Township (5)	Graphite Marble	South of Virginia Graphite Area		12
National Graphite (6)	Graphite in Paragneiss	Lot 11 Con. XXII	Cardiff	11
Virginia Graphite (7)	Graphite in Marble	Lot 35 Con. XVI	Monmouth	
				467

quartz and quartz-carbonate veins throughout the area mapped. Rare garnet porphyroblasts were observed in the mafic metavolcanics in the western part of the map-area. The predominant mafic mineral within the amphibolite is a dark green-black hornblende. Biotite occurs to varying degrees, and where the biotite content reaches a maximum (approximately 10 percent of the mafic mineral content), it imparts a layered appearance to these rocks.

The amphibolite in close contact and/or grading into the talcose zones is well-foliated to schistose, and composed predominantly of chlorite and biotite with minor carbonate.

The more intermediate metavolcanics occur as crudely banded dark green-grey to medium grey rocks showing a crude gneissic segregation of mafic (hornblende and biotite) and felsic (quartz-plagioclase) minerals into narrow layers (1 to 8 mm).

Shearing within the volcanic sequence produces well foliated hornblende (biotite) amphibolites in the mafic metavolcanics and rusty biotite gneiss in the intermediate metavolcanics. Where well foliated, the mafic metavolcanics contain well developed patches and smears of chlorite along foliation planes. Slight increases in the frequency of quartz-carbonate veining were also noted in sheared and foliated amphibolites.

Talc-rich zones occur within the mafic metavolcanics at or near the contacts with the intermediate metavolcanic units. They consist of 15 to 40 percent light grey talc, with varying amounts of anthophyllite, dolomite, tremolite, and accessory ferrous oxides. The weathering of the iron oxide minerals imparts a pinkish cast to the otherwise greenish grey, medium-grained rocks. Talc-rich zones are massive to poorly foliated, and show well developed anthophyllite rosettes where thicker more massive sections were observed.

Adjacent, and to the east of the talcose zones a narrow zone of medium to coarse-grained hornblende metagabbro to metadiorite occurs. These rocks are dark green-black, massive to poorly foliated; coarse-grained sections show crude lineation of hornblende crystals which parallel the regional foliation direction. Some sections show up to 25 percent quartz-plagioclase porphyroblasts and thus take on a more dioritic appearance and composition. Only the narrow contact zone of the Weslemkoon Batholith was mapped during this survey. It showed a consistent medium-grained biotite granodiorite composition, buff grey to pinkish in colour. Throughout this contact zone the granodiorite showed gneissic texture which parallels the regional foliation trend.

An approximately 2 km strike length of the talc area was mapped in detail. The 8 talcose zones located were concentrated to the east of the forest access road and within 300 m of the contact with the Weslemkoon Batholith.

Dubblestein Property, Cashel Township

Access to this property is via an old bush road which runs south off of the Weslemkoon Lake road, approximately 22 km west of the Village of Gunter and approximately 4 km east of McRae.

The general geology of this area is similar to that of the Madoc Talc and Mining Occurrence which is along strike to the northwest (Figure 1). Outcrop in this area is poorly exposed; to the west, a large system of swampy lowlands mark the contact between the mafic metavolcanics to the west and the gabbro-diorite zone and Weslemkoon granodiorite Batholith to the east. Talcose zones in this area occur just east and west of the swamp system and within 30 m of the gabbro-diorite contact zone.

The mafic metavolcanics consist of fine-grained, massive to poorly foliated, dark green to black hornblende amphibolite. The more foliated sections show chloritic smears developed along foliation planes.

Mafic intrusive rocks consist of medium- to coarse-grained dark green-black massive metagabbro to metadiorite. Coarser grained zones show minor chloritization of hornblende grains and 2 to 10 percent quartz-plagioclase porphyroblasts.

The talc zones on the Dubblestein Property vary from 2 to 15 m across strike and 15 to 50 m along strike. They occur near the contact between the mafic metavolcanics and the mafic intrusive contact zone. They are medium to buff, grey-green, medium-grained, massive to poorly foliated rocks composed of 10 to 30 percent talc, with accessory anthophyllite, chlorite, tremolite, and dolomite. Talc is fine- to medium-grained and occurs as flakes and crystals intergrown with tremolite and anthophyllite.

The poor exposure precludes further discussion of this area at this stage.

Cooper Area Talc Occurrences, Madoc Township

This area is accessible by road due west from the village of Cooper to the Black River, and south along the river for 2.5 km (Hewitt 1968, Map 2154).

The talc zones occur within a narrow belt of intermediate to mafic metavolcanics near the contact with the Elzevir trondhjemite Batholith which lies to the east. This metavolcanic sequence is the southern continuation of the sequence of metavolcanics hosting the Cashel Township talc zones discussed above. However, these rocks have been subjected to lower grades of metamorphism.

The general geology of Madoc Township has been discussed by Hewitt (1968). The metavolcanic units exposed in the Cooper area consist of fine-grained, foliated to massive, medium to dark green rocks which vary in texture and composition on outcrop scale. Coarser grained intermediate units are buff-tan to apple green in colour, and show banding with felsic zones (quartz-plagioclase) segregated parallel to the regional foliation direction. In general these intermediate units are best described as fine-grained dioritic zones within the more massive mafic volcanic suite. Coarser phases of the mafic units show the predominant amphibole to be acti-

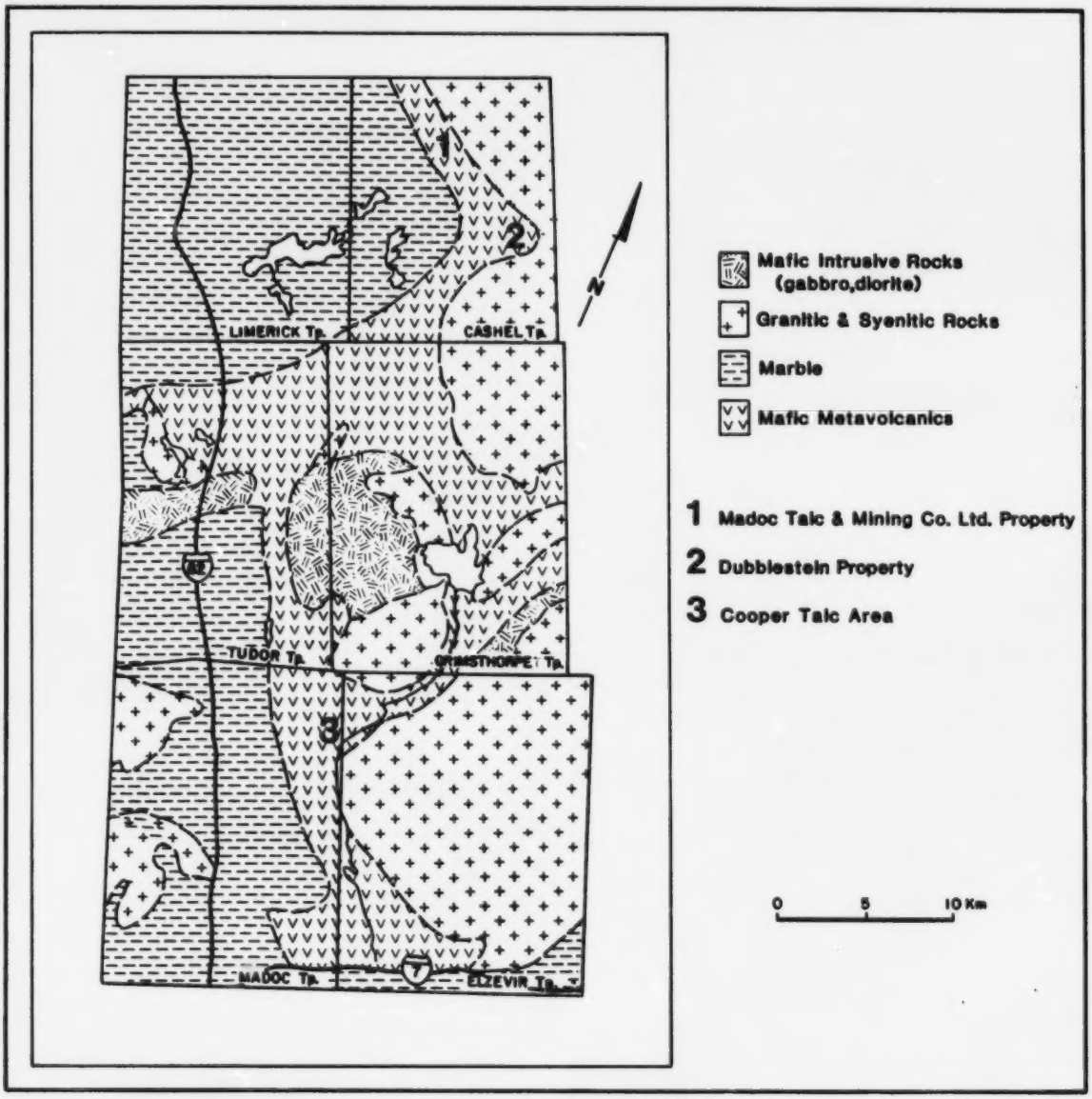


Figure 1—Location of talc study areas. Numbers refer to Table 1.

nolite with medium apple green to dark green colour, and prismatic to bladed crystal habit.

Felsic intrusive rocks of the Elzevir Batholith are equigranular, medium-grained and pinkish buff to medium grey granites. Minor phases of medium-grained light buff-grey biotite granodiorite gneiss occur within the more massive granite body. Late stage light grey, fine-grained aplitic phases occur both parallel to and cross-cutting the regional foliation direction within the granite body, and cutting metavolcanic units near the contact with the granite body.

The talc zones in this area consist of fine- to medium-grained, schistose to massive, light to buff greenish rock. Mineralogically this unit consists of varying amounts of talc, chlorite, tremolite, and carbonate, with talc content from 10 to 50 percent. These zones vary from thin laminae and fracture fills, 2 to 5 cm thick, to massive lenses up to 60 m thick, and 150 to 200 m in strike length (C.R. Young, prospector, Havelock, Ontario, personal communication, 1982).

Conclusions

Talc has a variety of uses depending on the colour and purity:

1. Ceramics: as a source of magnesia which acts as a filler
2. Paint: high-quality talc is used as a filler
3. Roofing: lower grades of off-colour material are used both as a filler and coating for tar paper and shingle
4. Paper: high-quality talc of good whiteness is used as a filler
5. Rubber: used for dusting molds to prevent sticking

Hewitt (1972) discusses the various uses of talc in detail. The talc zones mapped in all 3 areas show varying grades of talc with a variety of accessory minerals. If any zones are discovered of economic size a certain amount of beneficiation will be required to produce a high quality talc product.

Of the 3 areas discussed, the Cooper Zones have not been described in the previous literature. All occur on the eastern side of a continuous belt of intermediate to mafic metavolcanics (Tudor Volcanics), within 200 m of their contact with the large felsic intrusive bodies to the east. Less than 10 percent of this contact zone has been looked at in this survey, which leaves an extensive zone of apparently favourable geology warranting detailed study and prospecting.

Origin of Talc Deposits

Previous work in Cashel and Tudor Townships (Lumbers 1968, 1969) shows a zone of contaminated mafic rocks developed on the western border of the Weslemkoon granite, where the intrusive body cuts mafic metavolcanics. The zone dies out southward.

A metamorphic aureole of varying width marks the southern contact of the granite with the 'greenstone' host rocks; it dies out northward in Cashel Township. Comparable aureoles ring contacts in Tudor Township. Talc zones (of which the Madoc Talc and Mining Occurrence and the Dubblestein Property are two) are developed intermittently along the 'granite' margin outside the zone of contamination, but at this stage there is no evident relationship either to the contamination zone or to contact metamorphic effects.

The formation of talc (±chlorite, anthrophyllite, dolomite, magnesite, and tremolite) bodies appears to be a function of the host rock (metavolcanics) and intrusive metamorphic-metasomatic processes. The Madoc Talc and Mining Occurrence and the Dubblestein Property appear as linear zones formed parallel to the intrusive contact and the regional foliation direction, and are intimately associated with mafic intrusive rocks of diorite to gabbro in composition: the Cooper area talc zones occur in similar linear zones, however, their association with more mafic lithologies within the metavolcanics is only suggested by textural variations within the mafic metavolcanics (in zones of diorite rocks associated with the talc zones).

The position of the talc zones in linear belts suggests that they formed along zones of weakness developed during the intrusive event, at which time shearing may have produced more mafic segregations along shear zones. These zones permitted introduction of silica from the intrusive body.

Where syenitic or mafic intrusions cut the same metavolcanic sequence, no known talc zones have been located. The silica-poor nature of these intrusions, in contrast to the granitic bodies associated with the talc areas discussed, suggests that silica influx from the intrusive bodies may be significant to the formation of the talc zones.

Detailed petrologic studies and whole rock analyses may aid in refining these hypotheses.

Graphite

Marble and paragneiss hosted graphite properties were mapped in detail (scale 1:5000) in Monmouth and Cardiff Townships, approximately 40 km southwest of the Town of Bancroft. Reconnaissance mapping (scale 1:10 000) was undertaken over a marble belt in Olden Township, located approximately 50 km southwest of Perth (Figure 2). Emphasis was placed on those sections of the properties which contain concentrations of approximately 5 percent or more flake graphite (considered to be the approximate economic level).

Flake graphite is used primarily in the manufacture of lubricants, crucibles, refractory ware, carbon brushes, and foundry facings. At present there are no operating graphite mines within the Province.

Virginia Graphite Property

The Virginia Graphite Property, in Monmouth Township, and the property to the south, locally contain flake gra-

phite up to a maximum of 5 to 10 percent. Graphite flakes ranging from 1 to 8 mm in diameter occur within medium- (1 to 5 mm) to coarse-grained (greater than 5 mm) calcitic marbles. The metamorphic grade of the area is amphibolite facies.

The Virginia Property was operated from 1910 to 1913 by the Virginia Graphite Company. Four pits are exposed, the largest approximately 10 by 12 m and 10 m deep to the water level. The pit walls expose white to light grey, medium to coarse grained marble with sections of fine-grained biotite paragneiss irregularly dispersed within the marble. The vast majority of samples examined at the dump were barren, or contained trace (less than 1 percent graphite) amounts; the maximum mineralization observed was 5 percent flake graphite. Sparse outcrop in the area and the discontinuous nature of graphite zones in the pits precluded further geological observations.

Monmouth Township Graphitic Marble Belt

Highly graphitic calcitic marble boulders (maximum 15 to 20 percent graphite) found in the southern half of lot 35, concession XIV, initiated a detailed examination of the geology of the immediate area. Specimens may be viewed at the Wilberforce Rock Shop and in the Mineral Deposits Section. Mapping at a scale of 1:5000 revealed gradations between very pure, massive calcitic marbles to well foliated calc-silicate marbles.

The dominant lithology is a medium- to coarse-grained (3 mm to greater than 5 mm) calcitic marble with accessory graphite, phlogopite, diopside, and chondrodite. Chondrodite with lesser phlogopite are the dominant accessory minerals associated with graphite. Calc-silicate phases (tremolite with lesser quartz and feldspar) occur as isolated patches which weather out in relief within the marble.

The most graphitic marbles (1 to 2 percent graphite) observed in outcrop are closely associated with granite and pegmatite bodies. The granites and pegmatites locally contain up to 1 to 2 percent graphite with larger flake size (up to 1 cm in diameter) near or at the contact with marbles. The granites are white, medium to coarse

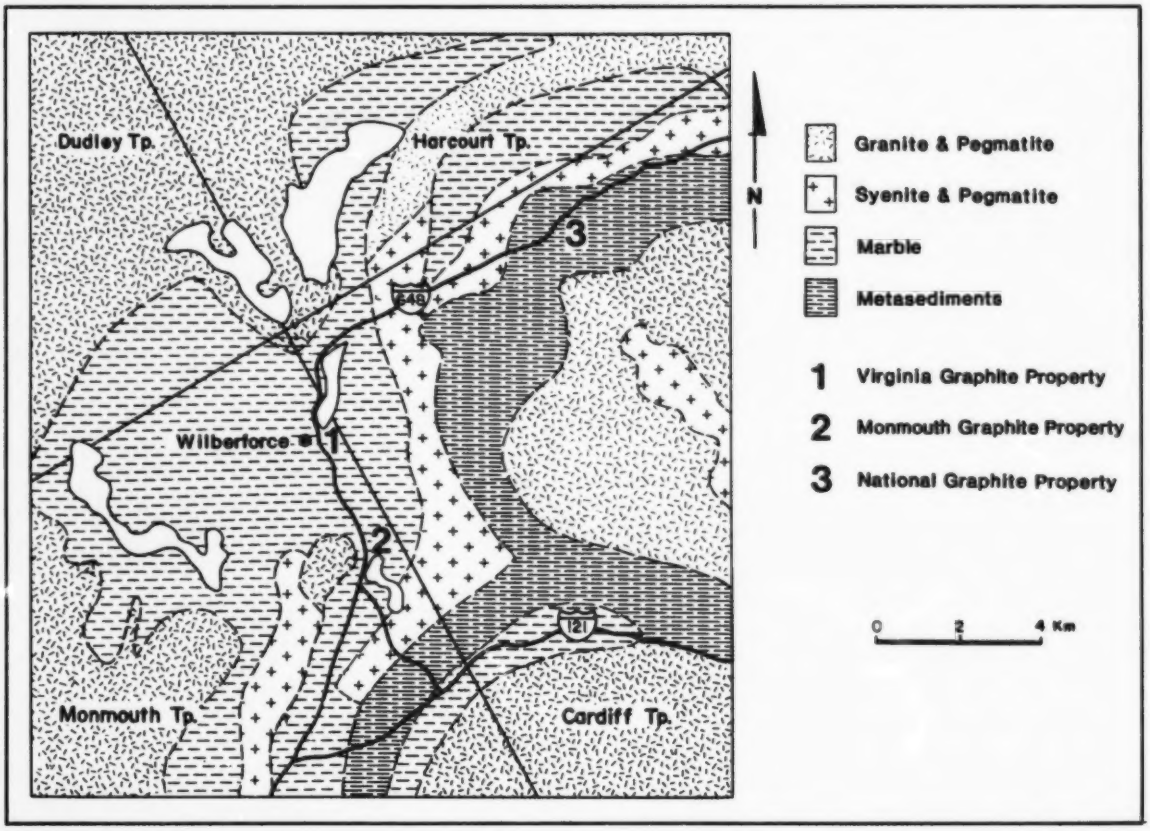


Figure 2—Location map of graphite properties studied.

grained, with numerous pegmatitic phases consisting of microcline crystals within a milky white quartz matrix. Similar to the Virginia Property, minor sections of biotite paragneiss occur within the sequence of marbles.

The restricted and low-grade nature of the graphitic zones within the marbles, the lack of good exposure, and the complex distribution of the associated granites and pegmatites do not indicate good potential for an economic graphite deposit in this area.

National Graphite Property

The National Graphite Property contains locally up to 25 percent graphite within biotite paragneiss and medium- to coarse-grained to pegmatitic granites. Property work was begun by the New York Graphite Company in 1912 when an open pit 18 m by 4.5 m and 12 m deep was excavated. A mill operated in 1915 and 1916. During 1951, 1300 m of drilling outlined an orebody of approximately 1 300 000 tonnes grading 4.1 percent carbon, with a 720 000 tonne section grading 5 percent (Hewitt 1965).

This year the property was mapped by the authors at a scale of 1:5000 along 100 m spaced lines, and at a scale of 1:1000 in a vertical section. The geology consists of a series of rusty, fine-grained flat-lying biotite paragneiss units (dipping 15° to 20°south) within a medium- to coarse-grained granite with pegmatite sections. The pegmatites grade from dominantly microcline with quartz intergrowths, to sections rich in coarse-grained to pegmatitic actinolite and hornblende. The paragneiss, where exposed along near vertical quarry faces, locally contains up to a maximum of 5 percent flake graphite (average flake size 1 to 2 mm), but averages 1 to 2 percent within a rusty feldspar-rich (20 to 30 percent feldspar) biotitic gritty unit. The medium- to coarse-grained granites which generally overlie the paragneiss contain coarser flake graphite (up to 1 cm) in quantities less than 1 percent, but locally up to 15 percent near the paragneiss contacts.

Olden Township

A belt of graphitic marbles was examined during reconnaissance mapping (scale 1:10 000) in western Olden Township, located approximately 50 km southwest of Perth. A marble body approximately 6 km^2 occurs on the western edge of the Mountain Grove Mafic Intrusion (Wolff 1982). A remnant of this calcitic marble body within the gabbroic intrusion hosts the Long Lake zinc-lead Mine which last operated from March 1973 to December 1974. The map-area lies within the Central Metasedimentary Belt, defined by Wynne-Edwards (1972). The metamorphic grade of the area is upper amphibolite facies.

Three main variations of marbles were observed within the carbonate metasedimentary belt:

1. a medium- to coarse-grained (3 to 5 mm) white crystalline calcitic marble with a granoblastic texture
2. a laminated white to light grey, dominantly medium-grained, calcitic marble containing slightly graphitic sections
3. fine- (0.5 mm) to medium-grained (3 mm) tremolite ± diopside ± scapolite calc-silicate assemblages

The calc-silicate minerals generally occur as fragments (5 cm to 0.5 m in size) of dominantly tremolite which stand out in marked relief within fine- to medium-grained, massive calcitic and dolomitic marbles. The 3 units grade into each other over outcrop scale and hence delineation of mappable units is not possible.

No graphite of economic quantity (>5 percent) was observed within the carbonate metasedimentary belt. Minor graphite (1 to 2 percent) sections were observed, primarily within the finer grained sections of the laminated marbles. Graphite mineralization of a continuous nature was not observed. Minor graphite (1 percent) was observed in the finer grained calc-silicate assemblages and was generally of an amorphous quality. Trace graphite (less than 1 percent) was the most common accessory within the marble belt and occurs in all of the units observed.

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